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Report to Congress: Solid Waste Disposal in the United States
Volume 2

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Washington, DC

Oct 88

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October 1988

Solid Waste

EPA

Report to Congress

Solid Waste Disposal in the United States

Volume II

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OCT 7 [illegible]

THE ADMINISTRATOR

Honorable George Bush
President of the Senate
Washington D.C. 20510

Dear Mr. President:

I am pleased to transmit the enclosed Report to Congress on Solid Waste Disposal in the United States. The report presents the results of our study carried out pursuant to Section 4010 of Subtitle D of the Resource Conservation and Recovery Act as amended by the 1984 Hazardous and Solid Waste Amendments.

The report addresses the land disposal of all non-hazardous solid waste covered by the existing Federal Subtitle D criteria (40 CFR Part 257). The adequacy of these Federal criteria as well as existing State Subtitle D programs is evaluated.

The report is published in two volumes. Volume I contains the Executive Summary and presents the conclusions and recommendations of the Subtitle D study. Volume II contains the detailed data collected during the study.

Sincerely,

Lee M. Thomas

Enclosure

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OCT 7

THE ADMINISTRATOR

Honorable James C. Wright
Speaker of the House
of Representatives
Washington D.C. 20515

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Lee M. Thomas

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CONTENTS

PAGE

Figures viii
Tables x
Exhibits xviii

CHAPTERS

1.0 INTRODUCTION AND BACKGROUND 1-1
1.1 SUBTITLE D OF THE RESOURCE CONSERVATION AND RECOVERY ACT 1-2
1.2 IMPLEMENTATION OF SUBTITLE D 1-2
1.3 HAZARDOUS AND SOLID WASTE AMENDMENTS OF 1984 1-5
1.4 IMPLEMENTATION OF THE HAZARDOUS AND SOLID WASTE AMENDMENTS 1-6

2.0 CONGRESSIONAL REPORT DATA COLLECTION PROJECTS 2-1
2.1 SCOPE AND METHODOLOGY 2-1
2.2 CHARACTERIZATION STUDIES OF SUBTITLE D WASTES 2-3
2.3 CHARACTERIZATION STUDIES OF SUBTITLE D FACILITIES 2-7
2.4 CHARACTERIZATION STUDIES OF STATE SUBTITLE D PROGRAMS 2-12
2.5 FUTURE DATA COLLECTION EFFORTS 2-14
2.6 REFERENCES 2-15

3.0 CHARACTERIZATION OF SUBTITLE D WASTE 3-1
3.1 MUNICIPAL SOLID WASTE 3-2
3.2 HOUSEHOLD HAZARDOUS WASTE 3-6
3.3 MUNICIPAL SLUDGE 3-11
3.4 MUNICIPAL WASTE COMBUSTION ASH 3-15
3.5 INFECTIOUS WASTE 3-17
3.6 TIRES 3-18
3.7 INDUSTRIAL NONHAZARDOUS WASTE 3-19
3.8 VERY-SMALL-QUANTITY GENERATOR WASTE 3-21

CONTENTS (CONTINUED)

PAGE

3.9 CONSTRUCTION AND DEMOLITION WASTE 3-30
3.10 AGRICULTURAL WASTE 3-30
3.11 OIL AND GAS WASTE 3-32
3.12 UTILITY WASTE 3-32
3.13 MINING WASTE 3-32
3.14 SUMMARY 3-33
3.15 REFERENCES 3-36

4.0 CHARACTERIZATION OF SUBTITLE D FACILITIES 4-1
4.1 LANDFILLS 4-2
4.1.1 General Profile 4-2
4.1.2 Characteristics of Leachate and Gas from Landfills 4-17
4.1.3 Design and Operation of Landfills 4-30
4.1.4 Analysis of Environmental and Human Health Impacts at Landfills 4-52
4.2 SURFACE IMPOUNDMENTS 4-87
4.2.1 General Profile 4-87
4.2.2 Design and Operation of Surface Impoundments 4-101
4.2.3 Analysis of Environmental and Human Health Impacts at Surface Impoundments 4-108

4.3 LAND APPLICATION UNITS 4-111
4.3.1 General Profile 4-111
4.3.2 Design and Operation of Land Application Units 4-124
4.3.3 Analysis of Environmental Impacts at LAUs 4-133
4.4 WASTE PILES 4-134
4.4.1 General Profile 4-136
4.4.2 Design and Operation of Waste Piles 4-146
4.5 SUMMARY 4-146
4.6 REFERENCES 4-150

CONTENTS (CONTINUED)

		PAGE
5.0	**CHARACTERIZATION OF STATE SUBTITLE D PROGRAMS**	**5-1**
5.1	QUALITY OF DATA FOR STATE PROGRAM CHARACTERIZATION	5-1
5.2	OVERVIEW OF STATE SUBTITLE D PROGRAMS	5-1
5.2.1	Program Organization and Management	5-1
5.2.2	Identification and Status of Subtitle D Facilities	5-5
5.2.3	Regulations and Permits	5-9
5.2.4	Enforcement Authorities	5-13
5.3	FACILITY-SPECIFIC STATE REGULATIONS	5-16
5.3.1	Landfills	5-16
5.3.2	Surface Impoundments	5-21
5.3.3	Land Application Units	5-25
5.3.4	Waste Piles	5-29
5.4	SUMMARY	5-31
5.5	REFERENCES	5-32

APPENDICES

A	Criteria for Classification of Solid Waste Disposal Facilities and Practices	A-1
B	Industrial Nonhazardous Waste Tables	B-1
C	Municipal Waste Landfill Capacity Problems	C-1
D	State Subtitle D Program Regulations for Municipal Waste Landfills, Surface Impoundments, Land Application Units, and Waste Piles	D-1
E	The Subtitle D Ground-Water Risk Model	E-1

FIGURES

NUMBER		PAGE
2-1	Subtitle D Study Methodology	2-2
3-1	Municipal Solid Waste Discarded and Energy Recovery from Municipal Solid Waste, 1960-2000	3-5
4-1	Universe of Subtitle D Units, by Percent	4-2
4-2	Number of Subtitle D Landfills by State	4-5
4-3	Ground-Water Regions of the United States	4-56
4-4	Distribution of Average Risk - Baseline	4-60
4-5	Cumulative Frequency of Average Risk - Baseline - All Landfills	4-61
4-6	Cumulative Frequency of Average Risk - Baseline - Only Landfills with Wells	4-63
4-7	Distribution of Average Risk - Baseline by Landfill Size (Normalized)	4-64
4-8	Cumulative Frequency of Average Risk-Baseline: Actual vs 10M Well	4-65
4-9	Distribution of Average Risk - Baseline by Net Infiltration Rate (Normalized)	4-67
4-10	Distribution of Resource Damage - Baseline	4-69
4-11	Cumulative Frequency of Resource Damage-Baseline: Use Value and Option Value	4-70
4-12	Cumulative Frequency of Resource Damage- Baseline: Use Value Only	4-72
4-13	Distribution of Resource Damage - Baseline by Size (Normalized)	4-73
4-14	Distribution of Resource Damage - Baseline by Infiltration Rate (Normalized)	4-74
4-15	Subset of Subtitle D Landfills Within CERCLIS Data Base	4-76
4-16	Observed Releases at Subtitle D Landfills on the NPL	4-78
4-17	Number of Active Subtitle D Surface Impoundments by Type	4-89
4-18	Number of Subtitle D Surface Impoundments by State	4-90
4-19	Number of Subtitle D Land Application Units by Type	4-113

FIGURES (CONTINUED)

NUMBER		PAGE
4-20	Number of Subtitle D Land Application Units by State	4-114
4-21	Weeks of Operation Per Year for Food Processing and Pulp and Paper Industries	4-130
5-1	States and Territories That Have Permit Requirements for all Subtitle D Facilities	5-12

TABLES

NUMBER		PAGE
3-1	Past and Projected Trends in Municipal Waste Composition	3-3
3-2	Hazardous Constituents of Common Household Commodities	3-8
3-3	Annual Generation Rates of Household Hazardous Waste in New Orleans, Louisiana, and Marin County, California	3-12
3-4	Potentially Hazardous Wastes in King County Municipal Solid Waste	3-14
3-5	Waste Quantity Disposed of in On-Site Industrial Facilities in 1985	3-22
3-6	Number of Small-Quantity Generators and Waste Quantity Generated by Waste Stream	3-24
3-7	Number of Small-Quantity Generators by Industry Group	3-26
3-8	Distribution of Off-Site and On-Site Management Practices for Small-Quantity-Generator Wastes	3-28
3-9	Estimated Number of Land Disposal Facilities Receiving Small-Quantity-Generator Wastes	3-29
3-10	Distribution of Surface Impoundments by Agricultural Production Facility	3-31
3-11	Number of Mining Surface Impoundments by the Material Mined	3-33
4-1	Universe of Subtitle D Facilities	4-1
4-2	Number of Subtitle D Landfills by Type of Facility	4-4
4-3	Number of Industrial Establishments with Landfills and Number of Landfill Units	4-6
4-4	Number of Landfills by Ownership Category	4-7
4-5	Number of Landfills by Acreage Category	4-8

TABLES (CONTINUED)

NUMBER		PAGE
4-6	Number of Industrial Establishments with Landfills by Total Area of Landfills in Each Establishment	4-9
4-7	Number of Landfills by Amount of Waste Received in 1984	4-10
4-8	Waste Quantities Disposed of in Industrial Landfills in 1985	4-11
4-9	Number of Industrial Establishments With Landfills by Annual Waste Quantity Disposed of in Them in 1985	4-12
4-10	Remaining Life of Municipal Solid Waste Landfills	4-13
4-11	Number of Municipal Solid Waste Landfill Establishments by Total Design Capacity	4-13
4-12	Number of Industrial Establishments with Landfills by Landfill Design Capacity Per Establishment	4-15
4-13	Design Capacity of Industrial Landfills by Industry Type	4-16
4-14	Age of Municipal Solid Waste Landfill Establishments	4-16
4-15	Age of Federally-Owned Municipal Solid Waste Landfill Establishments	4-17
4-16	Waste Composition of Municipal Solid Waste Landfill Establishments	4-18
4-17	Municipal Solid Waste Landfill Establishments Accepting Industrial Waste	4-18
4-18	Number of Municipal Solid Waste Landfill Establishments by Percentage of Liquids in Waste	4-19
4-19	Number of Industrial Establishments with Landfills Receiving Off-Site Waste and Off-Site Household Waste by Industry Type	4-19
4-20	Number of Small-Quantity-Generator Industrial Establishments that Dispose of Their Small-Quantity-Generator Waste in Their Landfills by Industry Type	4-20

TABLES (CONTINUED)

NUMBER		PAGE
4-21	Preliminary Data on Concentrations of Organic Constituents in Leachate from Municipal Solid Waste Landfills	4-22
4-22	Range of Various Inorganic Constituent and Parameter Concentrations in Leachate from Municipal Solid Waste Landfills	4-24
4-23	Preliminary Data on Concentrations of Organic Constituents in Leachate from Municipal Solid Waste Landfills According to Landfill Operations Start Date	4-26
4-24	Range of Various Inorganic Constituent and Parameter Concentrations in Leachate from Municipal Solid Waste Landfills According to Landfill Operations Start Date	4-27
4-25	Typical Composition of Gas from Municipal Solid Waste Landfills	4-31
4-26	Typical Trace Constituents in Municipal Solid Waste Landfill Gas	4-31
4-27	Numbers of Subtitle D Landfill Units Using Various Types of Release Prevention Methods	4-33
4-28	Number of Active and Planned Municipal Solid Waste Landfill Units by Type of Liner and Age of Disposal Unit	4-34
4-29	Number of Active Federally-Owned Municipal Solid Waste Landfill Units by Type of Liner and Age of Disposal Unit	4-34
4-30	Number of Active Municipal Solid Waste Landfills by Type of Leachate Collection System and Age of Unit	4-36
4-31	Number of Municipal Solid Waste Landfills by Type of Leachate Management Practice and Operating Status	4-37
4-32	Number of Active Municipal Solid Waste Landfills by Type of Run-on/Run-off System and Age of Unit	4-39
4-33	Number of Closed Municipal Solid Waste Landfills by Type of Run-on/Run-off System and Age of Unit	4-39

TABLES (CONTINUED)

NUMBER		PAGE
4-34	Number of Active Municipal Solid Waste Landfills with Gas Monitoring Detection or Recovery Systems by Age of Facility	4-39
4-35	Number of Municipal Solid Waste Landfills by Cover Type and Operating Status	4-41
4-36	Number of Municipal Solid Waste Landfills in Selected Terrains	4-42
4-37	Number of Federally-Owned Municipal Solid Waste Landfills in Selected Terrains	4-42
4-38	Number of Municipal Solid Waste Landfills by Location Criteria and Age of Facility	4-42
4-39	Number of Municipal Solid Waste Landfill Establishments by Underlying Predominant Soil Type	4-43
4-40	Number of Municipal Solid Waste Landfill Establishments by Horizontal Flow Rate in Ground Water	4-43
4-41	Source of Hydrogeologic Information Provided for Municipal Solid Waste Landfill Survey	4-44
4-42	Source of Water Information Provided for Municipal Solid Waste Landfill Survey	4-44
4-43	Number of Municipal Solid Waste Landfill Establishments Not Accepting Various Waste Types by Age of Facility	4-47
4-44	Number of Municipal Waste Landfill Establishments Using Separate Disposal Areas for Various Waste Types by Age of Facility	4-48
4-45	Number of Active Landfills with Monitoring Systems	4-50
4-46	Number of Municipal Solid Waste Landfill Establishments with Ground-Water and Surface Water Monitoring Systems by Age of Facility	4-50
4-47	Number of Federally-Owned Municipal Solid Waste Landfill Establishments with Ground-Water and Surface Water Monitoring Systems by Age of Facility	4-51
4-48	Number of Municipal Solid Waste Landfill Establishments with Air Monitoring Systems by Age of Facility	4-52

TABLES (CONTINUED)

NUMBER		PAGE
4-49	Number of Federally-Owned Municipal Solid Waste Landfill Establishments with Air and Methane Monitoring Systems by Age of Facility	4-53
4-50	Aggregate Data Relating to Environmental Contamination at Landfills in 1984	4-54
4-51	Number of Municipal Solid Waste Landfills Within One Mile of Active Drinking Water Wells	4-58
4-52	Number of Municipal Solid Waste Landfills by Distance to Nearest Surface Water Body Not Used for Drinking	4-79
4-53	Landfill Gas Migration Damage Cases	4-80
4-54	Estimates of Specific Subtitle D Surface Impoundment Numbers and Wastes Received Within Each Impoundment Category	4-91
4-55	Number of Industrial Establishments With Subtitle D Surface Impoundments and Number of Surface Impoundments by Industry Type	4-92
4-56	Number of Active Subtitle D Surface Impoundments Used Only for Back-Up or Surge Capacity by Industry Type	4-94
4-57	Number of Active Subtitle D Surface Impoundments by Ownership Category	4-95
4-58	Number of Active Subtitle D Surface Impoundments by Acreage Category	4-96
4-59	Number of Industrial Subtitle D Establishments With Active Surface Impoundments by Industry Type and Total Area of Surface Impoundments in Each Establishment	4-97
4-60	Number of Subtitle D Surface Impoundments by Surface Impoundment Type and Amount of Waste	4-98
4-61	Waste Quantity Disposed of in Industrial Subtitle D Surface Impoundments in 1985 by Industry Type	4-99
4-62	Number of Establishments with Surface Impoundments by Industry and Waste Quantity Disposed of in Them in 1985	4-100

TABLES (CONTINUED)

NUMBER		PAGE
4-63	Number of Small-Quantity-Generator Industrial Establishments That Dispose of their Small-Quantity-Generator Waste in Their Surface Impoundments by Industry Type	4-102
4-64	Number of Subtitle D Surface Impoundments Using Various Types of Release Prevention Methods	4-103
4-65	Number of Active Surface Impoundments with Monitoring Systems	4-107
4-66	Aggregate Data Relating to Environmental Contamination at Surface Impoundments	4-109
4-67	Number of Industrial Establishments with Subtitle D Land Application Units and Number of Land Application Units by Industry Type	4-115
4-68	Number of Subtitle D Land Application Units by Ownership Category	4-116
4-69	Number of Subtitle D Land Application Units by Acreage Category	4-118
4-70	Number of Active Industrial Subtitle D Establishments with Land Application Units by Industry Type and Total Area of Land Application Units in Each Establishment	4-119
4-71	Number of Subtitle D Land Application Units by Amount of Waste Received Annually	4-120
4-72	Waste Quantity Disposed of in Industrial Subtitle D Land Application Units in 1985 by Industry Type	4-121
4-73	Number of Establishments with Land Application Units by Industry Type and Waste Quantity Disposed of in Them in 1985	4-122
4-74	Number of Sites Contacted for Food Processing and Pulp and Paper Land Application Units Study by Industry Type	4-123
4-75	General Characteristics of Various Industrial Wastewaters Applied to Land	4-124

TABLES (CONTINUED)

NUMBER		PAGE
4-76	Number of Small-Quantity-Generator Industrial Establishments that Dispose of Their Small-Quantity-Generator Waste in Their Land Application Units by Industry Type	4-125
4-77	Number of Subtitle D Land Application Units Using Various Types of Release Prevention Methods	4-127
4-78	Application Techniques for Food Processing and Pulp and Paper Land Application Units by Industry Type	4-130
4-79	Number of Active Land Application Units with Monitoring Systems	4-132
4-80	Aggregate Data Relating to Environmental Contamination at Land Application Units	4-135
4-81	Number of Industrial Establishments with Subtitle D Wastes Piles and Number of Waste Piles by Industry Type	4-137
4-82	Waste Quantity Disposed of in Industrial Subtitle D Waste Piles in 1985 by Industry Type	4-139
4-83	Number of Establishments with Waste Piles by Industry Type and Waste Quantity Disposed of in Them in 1985	4-140
4-84	Number of Active Industrial Subtitle D Establishments with Waste Piles by Industry Type and Total Area of Waste Piles in Each Establishment	4-141
4-85	Waste Types Disposed of in Waste Piles	4-142
4-86	Number of Industrial Establishments with Subtitle D Waste Piles Receiving Off-Site Waste and Off-Site Household Waste by Industry Type	4-144
4-87	Number of Small-Quantity-Generator Industrial Establishments that Dispose of Their Small-Quantity-Generator Waste in Their Waste Piles by Industry Type	4-145
4-88	Management Methods for Waste Stored in Industrial Subtitle D Waste Piles by Industry Type	4-147
5-1	Sources of Subtitle D Funding	5-4
5-2	State Subtitle D Activities	5-6

TABLES (CONTINUED)

NUMBER		PAGE
5-3	Importance of Subtitle D Program Activities as Ranked by the States	5-6
5-4	Number of Open Dumps in the 1985 Inventory	5-8
5-5	40 CFR Part 257 Adoption by States and Territories and the District of Columbia	5-10
5-6	Number of Subtitle D Facilities with Permits	5-13
5-7	Number and Percentage of States with Enforcement Authorities	5-14
5-8	Number of Inspections at Subtitle D Facilities in 1984	5-15
5-9	Number of Facilities with at Least One Violation in 1984	5-15
5-10	Number of Subtitle D Landfills with Permits and Licenses	5-17
5-11	Number of Inspections of Subtitle D Landfills in 1984	5-20
5-12	Frequency of Inspection of Subtitle D Landfills	5-20
5-13	Number of Landfills by Type of Violation in 1984	5-21
5-14	Number of Subtitle D Surface Impoundments with Permits and Licenses	5-22
5-15	Number of Inspections of Subtitle D Surface Impoundments in 1984	5-24
5-16	Frequency of Inspection of Subtitle D Surface Impoundments	5-24
5-17	Number of Surface Impoundments by Type of Violation in 1984	5-25
5-18	Number of Subtitle D Land Application Units With Permits and Licenses	5-26
5-19	Number of Inspections of Subtitle D Land Application Units in 1984	5-28
5-20	Frequency of Inspection of Subtitle D Land Application Units	5-28
5-21	Number of Land Application Units by Type of Violation in 1985	5-29

EXHIBITS

NUMBER		PAGE
2-1	Data Collection Projects	2-4
3-1	Household Hazardous Wastes and Their Characteristics	3-7

Chapter 1

INTRODUCTION AND BACKGROUND

The 1984 Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) require the Environmental Protection Agency (EPA), by November 8, 1987, to submit a report to Congress addressing whether the criteria under Sections 1008(a) and 4004 of RCRA and 40 CFR Part 257 are adequate to protect human health and the environment from ground-water contamination. To meet this Congressional mandate, EPA has undertaken a Subtitle D study to assess:

- the impacts of nonhazardous waste landfills, surface impoundments, land application units, and waste piles on surface water, ground water, and air; and
- the implementation of the State nonhazardous waste programs.

The Subtitle D study includes a compilation and assessment of information on State programs, facilities, wastes, and contamination impacts. Information was obtained from EPA files, from the States, from published and unpublished literature, and from other sources. This volume presents the results of the data collection projects. The evaluation of the impacts of Subtitle D facilities on human health and the environment and the assessment of the adequacy of the current Subtitle D criteria are presented in Volume I of this Report to Congress. The conclusions made in Volume I are supported by the data presented in this volume. Chapter 2 of this volume presents details on the data collection projects. The next three chapters present the data according to the topics of waste characteristics (Chapter 3), facility characteristics (Chapter 4), and State programs (Chapter 5).

The remainder of this chapter provides the legislative and regulatory background of the Subtitle D program. Beginning with a discussion of the RCRA legislation that establishes Subtitle D, the chapter briefly reviews Federal and State implementation of Subtitle D from 1978 to 1981. (In 1981, Federal attention turned to the hazardous waste program under Subtitle C, and Federal funding of State Subtitle D implementation programs ended). The chapter then outlines the new Subtitle D provisions of HSWA and describes EPA's plans to implement these provisions. This Subtitle D report constitutes part of that implementation.

1.1 SUBTITLE D OF THE RESOURCE CONSERVATION AND RECOVERY ACT

Subtitle D of RCRA establishes a framework for coordinating Federal, State, and local governmental management of nonhazardous solid wastes. The Federal role in this arrangement is to establish the regulatory direction and provide technical assistance to States and Regions for planning and developing environmentally sound waste management practices. The actual planning and implementation of solid waste programs under Subtitle D remain State and local functions.

The primary planning and technical assistance provisions of Subtitle D are the following:

Section 4002--Federal Guidelines for State Plans. Requires EPA to promulgate guidelines to assist in the development and implementation of State solid waste management plans.

Section 4004--Criteria for Sanitary Landfills. Requires EPA to establish criteria for determining which facilities must be classified as sanitary landfills--that is, which facilities pose "no reasonable probability of adverse effects on health or the environment from the disposal of solid waste."

Section 4005--Prohibition of Open Dumps. Imposes a ban on open dumping in facilities that do not meet the criteria for sanitary landfills and requires EPA to publish an inventory of open dumps in order to assist States in upgrading or closing these facilities.

1.2 IMPLEMENTATION OF SUBTITLE D

In a series of rulemakings beginning in 1978, EPA began the process of implementing the provisions of Subtitle D. The Agency completed the guidelines for State plans in 1979 and began reviewing plans submitted by States. To aid the States in developing plans, EPA provided them with more than $50 million in annual grants. This financial assistance was terminated in 1981. EPA also finalized the "Criteria for Classification of Solid Waste Disposal Facilities and Practices" in 1979. These criteria are used by the States to classify facilities as either sanitary landfills or open dumps. After compiling these State facility classification data, EPA published the first inventory of open dumps in 1981.

Guidelines for State Solid Waste Management Plans--40 CFR Part 256

In compliance with RCRA Section 4002(b), on July 31, 1979, EPA promulgated guidelines (40 CFR Part 256) for the development and implementation of State solid waste management plans (44 FR 45066). These guidelines establish the minimum requirements for State plans and describe the procedures for State plan adoption, submission, and approval by EPA. Furthermore, the guidelines contain requirements and recommendations for solid waste disposal, resource conservation and recovery programs, facility planning and implementation activities, and public participation.

As the centerpiece of the Subtitle D program, the State solid waste management plan serves a critical function. Through this plan, each State identifies an overall strategy for protecting human health and the environment from the potentially adverse effects of solid waste disposal, specifies efforts for encouraging resource conservation and recovery, and formulates plans for providing adequate disposal capacity. The plan also describes the institutional arrangements that the State will use to implement its solid waste management program.

Under Subtitle D, EPA reviews State plans and approves those that meet the EPA guidelines. As of August 1987, EPA had fully approved 25 State solid waste management plans and partly approved another six.

Criteria for Sanitary Landfills--40 CFR Part 257

In compliance with RCRA Sections 4004(a) and 1008(a), EPA developed the "Criteria for Classification of Solid Waste Disposal Facilities and Practices" (40 CFR Part 257). These criteria provide minimum national performance standards for the protection of human health and the environment from solid waste disposal facilities. They establish the level of protection necessary to ensure that "no reasonable probability of adverse effects on health or the environment" will result from operation of the facility. A facility that meets the criteria is classified as a "sanitary landfill"; a facility in violation is classified as an "open dump" and must be upgraded or closed. The criteria, reproduced in Appendix A, were promulgated on September 13, 1979 (44 FR 53438). Minor amendments were issued in September 1981. The criteria can be summarized as follows:

1. A facility or practice must use special controls for location in floodplains.

2. A facility or practice must not adversely affect endangered species or their critical habitats.

3. A facility or practice must not cause discharges to surface waters or wetlands that are in violation of Section 402 or 404 of the Clean Water Act.

4. A facility or practice must not contaminate an underground drinking water source beyond the solid waste boundary or an alternative boundary.

5. A facility or practice must have specific restrictions on waste application to land used for food-chain crops.

6. A facility or practice must meet specific requirements for disease vector controls

7. A facility or practice must not engage in open burning of waste.

8. A facility or practice must have specific requirements for safety provisions to control explosive gases, fires, bird hazards to aircraft, and public access to the facility.

Implementation and enforcement of these Federal criteria under Subtitle D are primarily the responsibility of State and local governments. In addition, private citizens may use the RCRA citizen suit provisions (Section 7002) to bring actions in Federal court to enforce the criteria.

Inventory of Open Dumps

In compliance with RCRA Section 4005(b), EPA has published an inventory of open dumps in a series of five annual installments. The inventory is a listing of facilities that States have identified as failing to meet the criteria of 40 CFR Part 257. Based on State efforts in evaluating disposal facilities, the inventory serves two major functions:

1. It informs Congress and the public about the extent of the problem presented by disposal facilities that do not adequately protect public health and the environment.

2. It provides an agenda for action by identifying problem facilities routinely used for disposal that should be addressed by State solid waste management plans.

The first inventory installment was published on May 29, 1981. It reflected the participation of 55 States and territories and listed 1,209 facilities as open dumps. However, many States had not completed their inventory at the time of the publication (i.e., they had not evaluated all their sites against the criteria). The fifth and most recent installment of the inventory appeared in June 1985 and lists 1,856 facilities as open dumps. It represents the efforts of about 20 States to update their lists.

1.3 HAZARDOUS AND SOLID WASTE AMENDMENTS OF 1984

On November 8, 1984, the President signed into law HSWA, which modified virtually every part of RCRA, including Subtitle D. The amended RCRA Section 4010 requires EPA to "conduct a study of the extent to which the [criteria] . . . applicable to solid waste management and disposal facilities, including but not limited to landfills and surface impoundments, are adequate to protect human health and the environment from ground-water contamination." This study, which must be completed and delivered to Congress in report form by November 8, 1987, "shall also include recommendations with respect to any additional enforcement authorities which the EPA Administrator, in consultation with the Attorney General, deems necessary" to protect ground water.

The amended Section 4010 also requires EPA to revise the Subtitle D criteria by March 31, 1988, for facilities that receive household hazardous waste (HHW) or waste from small-quantity generators (SQGs). Such revisions must be necessary to protect human health and the environment and may take into account the "practicable capability" of facilities to implement the criteria. At a minimum, the revisions should require ground-water monitoring as necessary to detect contamination, establish location standards for new or existing facilities, and provide for corrective action, as appropriate.

The HSWA amends Section 4005 of RCRA to require each State to establish, by November 8, 1987, a permit program or other system of prior approval for facilities receiving small amounts of hazardous waste. Within 18 months of EPA's promulgation of revised criteria, each State must modify its permit program or alternative system accordingly. If a State fails to develop and implement an appropriate permit program, or another system of prior approval, by September 30, 1989, and EPA determines that the State has not developed an adequate program, EPA is given the authority to enforce the revised criteria at facilities with HHW or SQG waste.

1.4 IMPLEMENTATION OF THE HAZARDOUS AND SOLID WASTE AMENDMENTS

EPA has proceeded with implementing the HSWA Subtitle D requirements, conducting the Subtitle D study, and considering revisions to the Subtitle D criteria in a parallel effort. The tight HSWA schedule for completing the study, preparing the report to Congress, and promulgating the revisions to the criteria requires that these efforts take place concurrently.

Subtitle D Study

For the Subtitle D study, EPA has gathered existing information from the literature, States, EPA files, voluntary submissions of facility owners or operators, and any other available sources to identify and characterize Subtitle D wastes, facilities, and State programs.

Revisions to 40 CFR Part 257 Criteria

In a parallel effort, EPA is revising the Subtitle D criteria for those facilities that may receive SQG wastes and/or HHW. In compliance with RCRA Section 4010 these new requirements must address, at a minimum, ground-water monitoring, location criteria, and corrective action. The development of these revisions requires extensive contacts with States, local governments, and trade and environmental groups.

Chapter 2

CONGRESSIONAL REPORT DATA COLLECTION PROJECTS

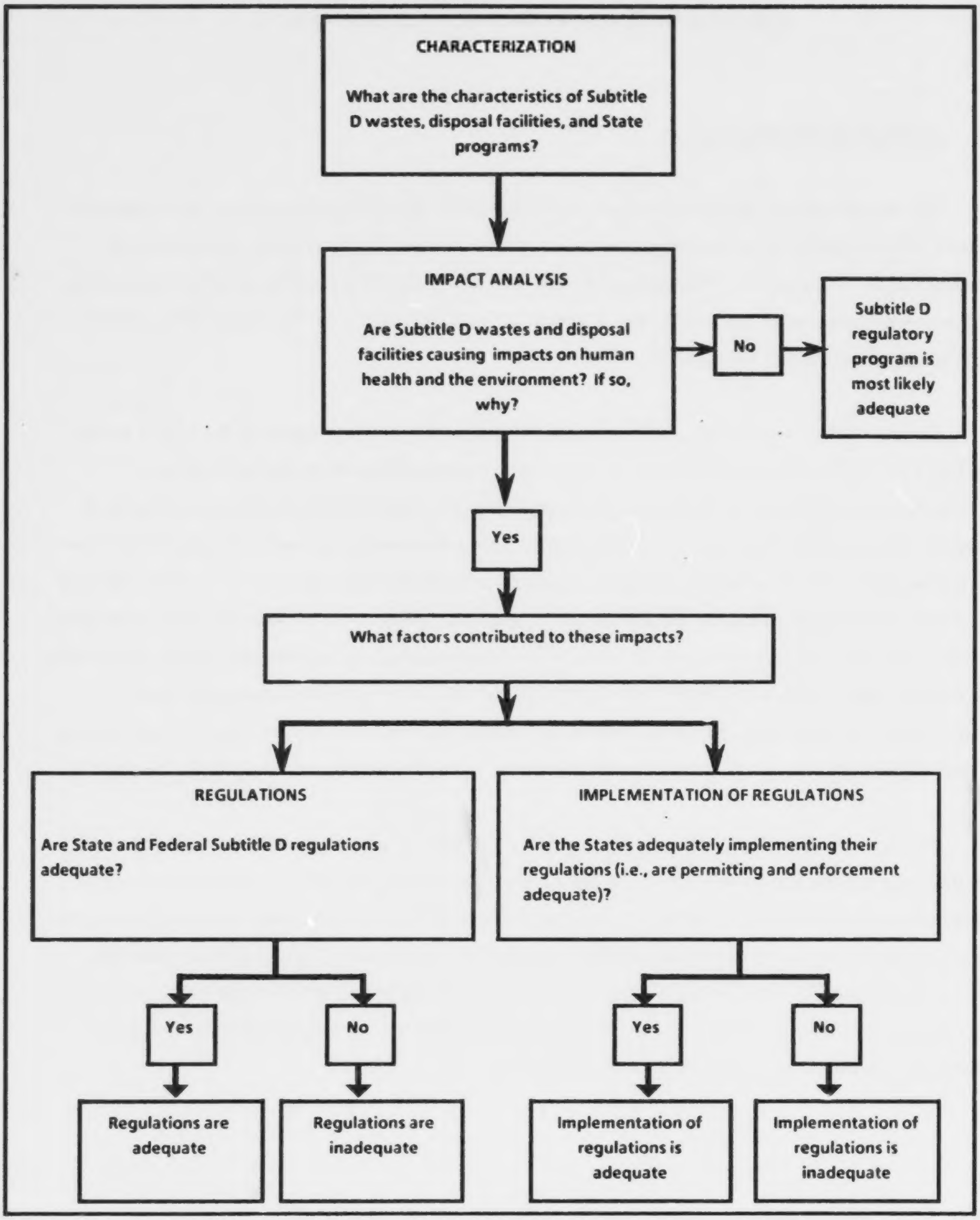
2.1 SCOPE AND METHODOLOGY

The Hazardous and Solid Waste Amendments (HSWA) require the Environmental Protection Agency (EPA) to assess the adequacy of existing Subtitle D criteria for preventing ground-water contamination. In particular, HSWA requires EPA to evaluate existing requirements for monitoring, prevention of contamination, and remedial action at Subtitle D facilities. To do this, EPA used the methodology illustrated in Figure 2-1.

Several studies were conducted that would characterize (1) the universe of Subtitle D waste (Section 2.2); (2) the universe of Subtitle D facilities with respect to environmental controls, environmental monitoring, and releases to the environment (Section 2.3); and (3) State Subtitle D programs (Section 2.4). Data on environmental controls and monitoring used at Subtitle D facilities were correlated with information on the composition of Subtitle D wastes and the number and type of releases that have occurred at these facilities. Using this information, EPA attempted to evaluate the nature and extent of the impacts of Subtitle D wastes and disposal facilities on human health and the environment. Federal and State criteria (40 CFR Part 257) and State implementation and enforcement activities were then evaluated to determine their roles in preventing or mitigating any adverse impacts of Subtitle D wastes and disposal facilities on human health and the environment.

The Agency collected available existing data on Subtitle D wastes, facilities, and State programs during the 3 years following the November 1984 passage of HSWA. The data sources for these projects included State and Federal program offices, published and unpublished literature, the regulated community, and technical research. Every effort was made to collect as much existing information as possible in all areas, within the constraints of the broad scope of the study, and time and resource limitations. Several original data collection efforts were also conducted, including surveys and fieldwork at a selected number of landfills.

Figure 2-1. SUBTITLE D STUDY METHODOLOGY


CHARACTERIZATION
What are the characteristics of Subtitle D wastes, disposal facilities, and State programs?
IMPACT ANALYSIS
Are Subtitle D wastes and disposal facilities causing impacts on human health and the environment? If so, why?
No
Subtitle D regulatory program is most likely adequate
Yes
What factors contributed to these impacts?
REGULATIONS
Are State and Federal Subtitle D regulations adequate?
IMPLEMENTATION OF REGULATIONS
Are the States adequately implementing their regulations (i.e., are permitting and enforcement adequate)?
Yes
No
Yes
No
Regulations are adequate
Regulations are inadequate
Implementation of regulations is adequate
Implementation of regulations is inadequate

For the purposes of this chapter, the projects have been grouped into the following categories:

- characterization studies of Subtitle D wastes,
- characterization studies of Subtitle facilities, and
- characterization studies of Subtitle D State programs.

This chapter describes the Subtitle D projects and their strengths and limitations. Exhibit 2-1 presents a list of the principal data collection projects.

2.2 CHARACTERIZATION STUDIES OF SUBTITLE D WASTES

The objective of the Subtitle D characterization studies was to determine the characteristics, volumes, and management methods of Subtitle D wastes. This objective was addressed by studies concerning several Subtitle D waste types, including municipal solid waste (MSW), industrial nonhazardous waste, household hazardous waste (HHW), and small-quantity generator (SQG) waste, and by literature reviews that were performed to support all of the technical areas covered by this report. The studies and literature reviews are summarized in the following subsections.

Source, Availability, and Review of RCRA Subtitle D Land Disposal Data Published Since 1980

This study[1] was one of the first efforts made in support of this Report to Congress. It was intended to locate available land disposal documents that would provide a foundation for the Subtitle D study. The report produced from this effort contains abstracts and bibliographic information on 110 documents. The abstracts are separated into eight categories: Overview, Design and Construction, Operation and Maintenance, Process Performance, Constituent Characteristics, Sampling and Methodology, Impacts, and Closure.

Characterization of Municipal Solid Waste in the United States, 1960 to 2000

This study[2] examines the historical quantities and composition of MSW. Quantities and sources of MSW are discussed in terms of both the historical quantities and the generation of the raw and manufactured source materials. Future municipal waste volumes and composition are predicted using (1) available forecasts of activities within various manufacturing industries and (2) calculations based on estimated waste generation per unit of material produced (these waste generation factors

Exhibit 2-1. DATA COLLECTION PROJECTS

Subtitle D Waste Characterization Studies

- Source, Availability, and Review of RCRA Subtitle D Land Disposal Data Published Since 1980--Reviews and abstracts of recent literature relevant to the Subtitle D study
- Characterization of Municipal Solid Waste in the United States, 1960 to 2000--Inventory and forecast of municipal solid wastes in the U.S.
- Summary of Data on Industrial Nonhazardous Waste Disposal Practices--Summary of non-State data on solid waste characteristics and solid waste disposal practices
- A Survey of Household Hazardous Wastes and Related Collection Programs--Review of existing data on the characteristics of HHW and analysis of HHW collection programs
- National Small Quantity Generator Survey--Survey to characterize SQG waste volumes and disposal practices
- Hazardous Waste Generator Data and Characteristics of Sanitary Landfills in Selected Counties in Florida--Case history of Florida disposal of small quantity generator hazardous wastes

Subtitle D Facility Characterization Studies

- Census of State and Territorial Subtitle D Nonhazardous Waste Programs--Mail survey of data on State Subtitle D programs and Subtitle D facilities
- Municipal Solid Waste Landfill Survey--Summary of data from State survey of municipal landfills
- Industrial Facilities Telephone Survey--Summary of data from telephone survey of 17 industries
- Critical Review and Summary of Leachate and Gas Production from Landfills--Summary and evaluation of data on quality of leachate from municipal landfills
- Evaluation of a Landfill with Leachate Recycle--Case study of the Lycoming County, PA, landfill with a major emphasis on experiences with leachate recirculation
- Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics--Review of municipal landfill leachate data
- Gas Characterization, Microbiological Analysis, and Disposal of Refuse in GRI Landfill Simulators--GC/MS analysis of landfill gas samples from the Center Hill lysimeters
- Landfill Gas Update: Summaries of Technical Reports--Summaries of six studies relating to landfill gas production, characteristics, and recovery
- Evaluation of NPL/Subtitle D Landfill Data--Summary of data on former Subtitle D facilities that are now on the NPL or are candidates for the NPL
- Ground-Water and Surface Water Contamination from Municipal Solid Waste Landfills--Summary of facility characteristics and environmental impacts at the damage cases

State Subtitle D Program Characterization Studies

- Review of State Enforcement Authorities Under RCRA Subtitle D--Compilation of data on States' enforcement authorities with respect to Subtitle D management and disposal facilities
- Updated Review of Selected Provisions of State Solid Waste Regulations--A review of liner, leachate collection, final cover, ground-water monitoring, and corrective action requirements
- State Regulatory Equivalency Analysis of the U.S. EPA Classification Criteria for Solid Waste Management Facilities (40 CFR Part 257) -- A State by State determination of the comparability of State Subtitle D regulations to those contained at 40 CFR Part 257
- State Subtitle D Regulations on Municipal Waste Landfills, Surface Impoundments, Waste Piles and Land Application Units--Review of State Subtitle D regulations
- National Solid Waste Survey (ASTSWMC)--Mail survey of data on State Subtitle D programs

are changed over time to account for technical changes). The results are reports and forecasts of the quantities and composition of MSW for the period 1960 to 2000. The report was updated in 1988[3].

Summary of Data on Industrial Nonhazardous Waste Disposal Practices

This study[4] characterized the wastes and management methods of those industries likely to be most affected by regulatory changes required under HSWA. The 22 industries studied were selected because: (1) they produced the largest quantities of nonhazardous waste, (2) they had the highest probability for management in on-site land disposal units (i e , landfills, surface impoundments, land application units, or waste piles), and (3) they produced the most potentially toxic wastes.

Data were collected from non-State sources only, since separate studies were being done to gather Subtitle D information from State sources The study used published and unpublished literature to obtain data in the following areas:

- characteristics of nonhazardous waste generated,
- amounts of each waste type,
- amounts processed by different on-site waste management facilities,
- numbers and characteristics of on-site units,
- environmental impacts of on-site units, and
- amounts transported to different off-site units.

This study revealed several limitations in the quality and content of available data on industrial waste generation and management. Data completeness varied according to data type: most industries had complete data on waste type, waste quantities were available for fewer industries, estimates of waste quantities managed on the site were available for fewer yet, and almost no estimates were available on the numbers of on-site land disposal units within an industry. No nationwide data were available on the typical design characteristics of on-site land disposal units, the location or prevalence of ground-water monitoring at these units, or their impacts on the environment.

A Survey of Household Hazardous Wastes and Related Collection Programs

The legislative history of HSWA indicates that a major Congressional concern in passing the law was the large amount of HHW and SQG waste managed at Subtitle D facilities that may not be suited to receive such hazardous wastes. In order to better characterize and quantify HHW, EPA conducted the Survey of Household Hazardous Wastes and Related Collection Programs.[5] This study is a literature survey that presents information on the makeup of HHWs, their presence in the municipal waste stream, and their impacts on solid waste management. It also presents information on State HHW programs and special HHW collection programs and includes three case studies of HHW programs in the United States. No nationwide data were available on types and quantities of HHW, environmental impacts of HHW by disposal at municipal landfills, and administration of HHW collection programs.

National Small-Quantity Generator Survey

EPA sought to better characterize SQG waste and management practices by conducting the National SQG Survey.[6] Even though this survey was completed in 1985, it addresses distinctions made by the March 24, 1986, rule on SQG exemption to regulations under Subtitle C of the Resource Conservation and Recovery Act (RCRA). The SQG exemption was amended to apply only to "conditionally exempt" SQGs of less than 100 kilograms per month of hazardous waste, or very-small-quantity generators (VSQGs). This survey was mailed to 50,000 industrial establishments that generate less than 1,000 kilograms of hazardous waste per month, so it addresses both SQGs and VSQGs. The report includes a summary and analysis of the 1,900 responses to the survey. The results include the following:

- the estimated number of SQGs and VSQGs and the total quantities of hazardous waste they generate,
- descriptions of the different SQG and VSQG wastes generated by the 22 major industry groups surveyed, and
- estimates of the management practices currently used by SQGs and VSQGs in the primary industry groups targeted in the survey.

Hazardous Waste Generator Data and Characteristics of Sanitary Landfills in Selected Counties in Florida

In a further attempt to characterize SQG waste and management practices, EPA obtained data from the Florida Department of Environmental Regulations.[7] These data were collected in 1983 in order to implement Florida's Local Government Hazardous Waste Management Program, which required every county in the State to complete assessments of hazardous waste generation and management. The final report contains data from all 67 counties in the State. Those data cover SQG waste types, amounts, sources, and management and disposal practices.

2.3 CHARACTERIZATION STUDIES OF SUBTITLE D FACILITIES

Facility characterization studies were conducted to gather information in the following areas: numbers and general characteristics of Subtitle D facilities, facility design and operating practices, and the characteristics of leachate and gas from Subtitle D facilities. These data are needed to assess the likelihood of releases to the environment from Subtitle D facilities, and the probable impact on human health and the environment in the event of such releases. Studies undertaken in this effort are described below.

Census of State and Territorial Subtitle D Nonhazardous Waste Programs

The State Subtitle D census[8] was conducted to collect comprehensive data on Subtitle D facilities and regulatory programs across the country. The Association of State and Territorial Solid Waste Management Officials was very helpful to EPA in developing the census. The census was mailed to Subtitle D regulatory program offices in all States and territories. Telephone follow-ups were used to supplement the questionnaire and minimize errors due to inconsistency or nonresponse.

Part I of the questionnaire was designed to produce a directory of State agencies that administer Subtitle D programs and to determine their level of funding and program emphasis. The remaining three parts elicited information on numbers of facilities, design and operating characteristics, regulations, enforcement activities, and data availability. Parts II, III, and IV are divided into information concerning landfills, land application units, and surface impoundments.

The census topics included the following:

1. State organization and resources
    a. State agencies
    b. Budget
    c. Budget sources
    d. Labor hours
    e. Activities
    f. Projections

2. Facilities
    a. Total number
    b. Total number by facility subcategory
    c. Total number by State and Region
    d. Total number by ownership, acreage, and amount of waste
    e. Total number using key design and operating features

3. Program characteristics
    a. Regulatory requirements
    b. Permitting and licensing
    c. Inspections
    d. Violations
    e. Monitoring and release prevention

The census data are limited because of imperfect and inconsistent recordkeeping among the State and territorial regulatory offices. When asked to rate the quality of their information, respondents rated landfill data highest, surface impoundment data lowest, and land application data somewhere in between.

Municipal Solid Waste Landfill Survey

The Municipal Solid Waste Landfill Survey[9] was performed in 1986 and 1987 to confirm the results and fill the data gaps from the State Subtitle D census. The EPA asked each State for a list of active municipal solid waste landfills (MSWLFs) within the State. A compilation of all of the States' lists indicated that there were 7,600 MSWLFs in the nation. As a result of some telephone follow-ups, the estimate of the total number of active MSWLFs in the nation was lowered to approximately 6,000. This estimate was made after careful consideration of the Subtitle D census data, which indicated there were 9,300 MSWLFs.

After defining the universe of approximately 6,000 facilities, EPA selected a statistical sample set of 1,250 MSWLFs. This set consisted of 200 large facilities (more than 500 tons/day of waste) and 1,050 small facilities (less than 500 tons/day of waste). The 200 large facilities represent 45 percent of all large MSWLFs, and the 1,050 small facilities represent approximately 11 percent of all small MSWLFs. A questionnaire was mailed to the 1,250 facilities, followed by a telephone contact in order to maintain consistent responses.

The Survey provided detailed site-specific data on the number, size, ownership, age, location, design and operating characteristics, monitoring practices, waste management techniques, and other aspects of MSWLFs. The actual survey responses from the sample set were projected upward to a level representing the entire universe of MSWLFs. The scaling factors used consider the composition of the sample set with respect to the size of the facilities. The results provided by this survey are subject to sampling and non-sampling errors Sampling errors result from the fact that only a fraction of the population is surveyed. Non-sampling errors include mistakes in interpreting questions, writing down responses, coding, and programming.

Industrial Facilities Survey

The Industrial Subtitle D Facilities Survey[10] was undertaken to fill data gaps in the Subtitle D census results for industrial landfills, surface impoundments, land application units, and waste piles. Seventeen major industries were surveyed, including electric power generation, water treatment, petroleum refining, five categories of chemical manufacturing, and nine categories of other manufacturing. Only telephone survey results are presented here.

Approximately 18,000 of the 150,000 Subtitle D facilities in the United States falling in these categories were randomly selected and then contacted by telephone. Of the 18,000 facilities, 11,000 generated Subtitle D wastes, and 2,800 had landfills, surface impoundments, land application units, or waste piles on-site. The telephone survey responses were compiled and then extrapolated to determine nationwide statistics on industrial Subtitle D waste management.

The Industrial Facilities Survey provided data on the number and acreage of industrial Subtitle D establishments as well as the waste management techniques used and the waste quantity received by these establishments. The number of actual survey responses was projected upward to a level representing all of the industrial Subtitle D facilities located at the 17 industries surveyed. The scaling factors used consider the composition of the sample set with regard to the size and industry type of the facilities. The results of this survey are subject to the same errors discussed above for the Municipal Solid Waste Landfill Survey.

Critical Review and Summary of Leachate and Gas Production from Landfills

In an effort to determine the risks posed by leachate and gas produced at Subtitle D facilities, EPA conducted several leachate and gas characterization studies. The first of these studies, Critical

Review and Summary of Leachate and Gas Production from Landfills,[11] examines research efforts and field investigations of landfill leachate and gas production and management. The purpose is to provide an inventory of available techniques for containment, control, and treatment of landfill gas and leachate. This inventory will serve as a reference of state-of-the-art technologies against which data on current management practices at Subtitle D facilities can be evaluated

Evaluation of a Landfill with Leachate Recycle

To further evaluate technologies for leachate management, EPA collected data from the Lycoming County, Pennsylvania, landfill, which was designed to use leachate recirculation as a control technology. The EPA chose this facility for study in part because the county's solid waste department had kept detailed records of the landfill operations, including data on leachate quantity and quality. This study[12] examines the effectiveness of leachate recirculation as a control technology, and examines the feasibility of leachate recirculation for different locations and various types of landfill cover. New techniques are evaluated and problems are identified for different landfill designs.

Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics

The purpose of this report[13] was to present information on the quality of leachate from MSWLFs. The data gathered for this report were used to help evaluate the potential human health and environmental impacts from MSWLFs. Values for traditional leachate parameters, inorganic constituents, and organic constituents are presented.

Gas Characterization, Microbiological Analysis, and Disposal of Refuse in Gas Research Institute Landfill Simulators

To better characterize both the trace volatile constituents in landfill gas and the microbial content of refuse in landfills, EPA obtained information from the Gas Research Institute (GRI).[14] The GRI had conducted a five-year study to describe the microbiology of refuse, the production of trace constituents in landfill gas, and methane production and gas enhancement techniques at landfills. Sixteen lysimeters were used to simulate landfills and to monitor gas production. The results of this study will be used as a reference for the technical and environmental impact analysis of methane production and gas enhancement at Subtitle D facilities.

Landfill Gas Update: Summaries of Technical Reports

This report[15] summarizes six studies performed on landfill gas production, characteristics, and recovery. The purpose of the report is to provide the Subtitle D study with current research information related to landfill gas.

Evaluation of NPL/Subtitle D Landfill Data

This study[16] focused on the 184 Subtitle D landfills that were either on or proposed for the National Priority List (NPL) in May 1986. Data for these sites were examined in an effort to identify common characteristics of those Subtitle D landfills known to have resulted in adverse environmental impacts (i.e., those on the NPL). Data were obtained from the CERCLIS data base, NPL site descriptions, MITRE Hazard Ranking System (HRS) data base, and other EPA data sources. Site characteristics that were evaluated include the following: operating dates; NPL rank; HRS score; date listed or proposed for the NPL; site ownership; open-dump status, financial obligations and expenditures for cleanup; site size; hazardous constituents; waste types; and observed releases to ground water, surface water, and air. These characteristics and others, such as wastes received or problems encountered, were entered onto a separate data base for future consideration.

Case Studies on Ground-Water and Surface Water Contamination From Municipal Solid Waste Landfills

This report[17] identified and described human health and environmental impacts (excluding impacts from subsurface gas migration) that have resulted from the operation of MSWLFs and, where possible, determined what role the design, operation, and location of the facility played in creating the problem. Numerous sources of information were reviewed to identify MSWLFs that have resulted in some type of adverse impact to ground water, surface water, or wildlife. Once a site was identified as having caused some type of damage, the information on that site was further evaluated to determine:

- the severity of the damage

- whether there was a potential relationship between the damage and the design, operation, or location of the MSWLF, and

- the type of corrective action, if any, that may have been implemented.

2.4 CHARACTERIZATION STUDIES OF STATE SUBTITLE D PROGRAMS

State Subtitle D programs were studied to determine the:

- equivalency of State Subtitle D regulations with those contained at 40 CFR Part 257,
- State powers and authorities to enforce Subtitle D programs, and
- State Subtitle D program organization, staffing, resources, monitoring, enforcement activities, and priorities in solid waste management.

The information available from the census was described in Section 2.3 above. Information from the other projects is discussed in this Section.

Review of State Enforcement Authorities Under RCRA Subtitle D

Section 4010 of HSWA specifies that the Subtitle D Report to Congress must include recommendations with respect to additional enforcement authorities necessary to protect human health and the environment from ground-water contamination. To determine this, EPA conducted a study[18] to compile information on existing State enforcement powers and authorities with respect to Subtitle D management and disposal facilities and practices. This study had the following three objectives:

1. list all State and territorial Subtitle D enforcement powers and authorities,

2. note national and regional patterns in Subtitle D enforcement authorities and evaluate strengths and weaknesses in meeting Subtitle D requirements, and

3. present recommendations regarding the establishment of additional Federal enforcement authorities necessary to carry out Subtitle D objectives.

The information was compiled through a review of available information sources on State Subtitle D laws and regulations. Patterns were then examined at the national and EPA regional levels. The enforcement data are limited because only solid waste laws and regulations were reviewed. Applicable enforcement authorities may be found in other State statutes or regulations. In addition, due to time limitations, the States did not review the results of this study.

State Regulatory Equivalency Analysis of the U.S. EPA Classification Criteria for Solid Waste Management Facilities (40 CFR PART 257)

Since the current Subtitle D program is primarily a State-administered program, EPA conducted this study[19] to determine the equivalency of each State's Subtitle D regulations with those regulations contained at 40 CFR Part 257.

This study presents the results of the State-by-State determination in both matrix and narrative form. State Subtitle D requirements were analyzed for comparability to the requirements contained at 40 CFR Part 257. Those determined to be not comparable were further analyzed to see if they constituted a "distinctive and innovative approach" that nevertheless provided for protection of human health and the environment.

State Subtitle D Regulations on Municipal Waste Landfills, Surface Impoundments, Waste Piles and Land Application Units

EPA conducted mail and field surveys of the States, to evaluate State implementation of the Subtitle D criteria. This project resulted in a draft report[20] in which current State regulations are summarized and analyzed. The most current regulations were obtained from each State as one of its responses to the State Subtitle D census. Current regulations were received from all States and all but two territories. The draft report is presented in four volumes, with one each for MSWLFs, surface impoundments, land application units, and waste piles. Regulations reviewed cover the following categories:

- permitting and administrative requirements,
- design criteria,
- operation and maintenance criteria,
- location standards and restrictions,
- monitoring requirements,
- closure and post-closure requirements, and
- financial responsibility.

Appendix D presents a series of tables summarizing the key findings of this report.

Updated Review of Selected Provisions of State Solid Waste Regulations

The three provisions of State solid waste regulations reviewed in this document[21] were facility design requirements (i.e., requirements for liners, leachate collection systems, and final cover); ground-water monitoring requirements; and requirements for corrective action. This analysis was done to support the revisions to the current Federal Subtitle D Criteria. Results from this review are presented in Chapter 5 of this report, with the results of the study described above.

National Solid Waste Survey

An additional study that assessed State implementation of the Subtitle D criteria was the National Solid Waste Survey.[22] In 1983, the Association of State and Territorial Solid Waste Management Officials, together with the EPA Office of Solid Waste and the National Solid Wastes Management Association, formulated and distributed this survey to solid waste management officials in all States and territories. A total of 44 States and territories responded, providing data on the following topics: solid waste agency organization and function; staffing resources; budget resources; solid waste treatment, storage, and disposal facility statistics; facility evaluation, monitoring, and enforcement activities; SQGs; and priorities in solid waste management.

2.5 FUTURE DATA COLLECTION EFFORTS

To fill the numerous data gaps identified by the study, several information-gathering efforts have been planned and some are under consideration. The Agency will be proposing to amend the current Federal Subtitle D criteria (40 CFR Part 257) with a notification requirement for industrial facilities. These facilities will be required to provide information regarding waste types disposed at the facility, the location and types of units at the facility, and general exposure information such as the number of drinking water wells within one mile of the facility. In addition, the Agency will be developing a plan for filling remaining data gaps on industrial facilities.

For MSWLFs, more sampling and analysis of leachate has been planned. Newer sites will be visited and complete facility information will be obtained. In addition recycling and source reduction efforts are being considered.

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Chapter 3

CHARACTERIZATION OF SUBTITLE D WASTE

Subtitle D wastes are solid wastes regulated under Subtitle D of the Resource Conservation and Recovery Act (RCRA). They are not subject to the hazardous waste regulations under Subtitle C of RCRA. Solid wastes regulated under RCRA are defined in 40 CFR Part 257 as:

> ...any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved materials in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act, as amended (86 Stat. 880), source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended.

In accordance with the above-mentioned definition, the following categories of Subtitle D wastes have been identified:

- Municipal solid waste
- Household hazardous waste
- Municipal sludge
- Municipal waste combustion ash
- Infectious waste
- Waste tires
- Industrial nonhazardous waste
- Very-small-quantity generator hazardous waste (< 100 kg/month)
- Construction and demolition waste
- Agricultural waste
- Oil and gas waste
- Utility waste
- Mining waste.

The following sections define each category and discuss the data collected on waste characteristics, generation rates, and management practices.

3.1 MUNICIPAL SOLID WASTE

Municipal solid waste (MSW) is a mixture of household, institutional, commercial, municipal, and industrial solid waste. The composition of MSW is variable, but generally more than half (by weight) is paper products and yard waste. In 1986, approximately 158 million tons of MSW were generated in the United States. Approximately 141 million tons were discarded, mostly (93 percent) in landfills. The characteristics, quantities, and management of MSW are discussed in this section.

Characteristics of Municipal Solid Waste

Reports on the composition of MSW vary widely.[1,2,3] This variation is attributable in part to regional differences in climatic, seasonal, and socioeconomic factors. It is also the result of reporting methods that differ in measurement techniques, definitions of MSW, and categories of waste constituents. The variation in these reports makes it difficult to construct a national profile of MSW composition.

The best source of information on MSW characteristics is Characterization of Municipal Solid Waste in the United States, 1960 to 2000.[1,4] This study constructs a national profile of MSW by evaluating a wide range of waste composition data and comparing this information to materials production data in a national materials balance model. It relates historical information on waste generation to information on the production of durable and nondurable materials. The study does not estimate industrial nonhazardous wastes, small-quantity-generator hazardous wastes, or municipal sludge components of MSW.

As shown in Table 3-1, the MSW characterization study reported that paper products (paper and paperboard) and yard wastes made up about 56 percent of the MSW discarded in 1986. Table 3-1 also shows the estimated tonnage of materials discarded for the years 1970 and 2000. These data suggest that the use of paper and plastics is increasing.[1,4]

Municipal solid wastes generated from households, institutions, and commercial establishments may contain microorganisms. For example, household discards that may contribute microorganisms include facial tissue, soiled disposable diapers, and putrescible foods. Relatively

Table 3-1. PAST AND PROJECTED TRENDS IN MUNICIPAL WASTE COMPOSITION

Materials	1970		1986		2000	
	Million Tons/Yr[a]	%	Million Tons/Yr[a]	%	Million Tons/Yr[a]	%
Paper and paperboard	36.5	32.4	50.1	35.6	66.0	39.1
Glass	12.5	11.1	11.8	8.4	12.0	7.1
Metal	13.5	12.0	12.6	8.9	14.4	8.5
Plastic	3.0	2.7	10.3	7.3	15.6	9.2
Rubber and leather	3.0	2.7	3.9	2.8	3.8	2.3
Textile	2.0	1.8	2.8	2.0	3.3	2.0
Wood	4.0	3.6	5.8	4.1	6.1	3.6
Food waste	12.8	11.4	12.5	8.9	12.3	7.3
Yard waste	23.2	20.6	28.3	20.1	32.0	19.0
Other nonfood product waste	0.1	--	0.1	--	0.1	--
Miscellaneous inorganic waste	1.9	1.7	2.6	1.8	3.2	1.9
Total[b]	112.5	100	140.8	100	168.8	100

SOURCE: References 1 and 4.

[a] After materials recovery has taken place

[b] Percentages are rounded and may not total 100 percent.

high densities of microorganisms in MSW have been reported in the literature with paper products, garden waste, and food waste contributing the most.[5]

Quantities of Municipal Solid Waste

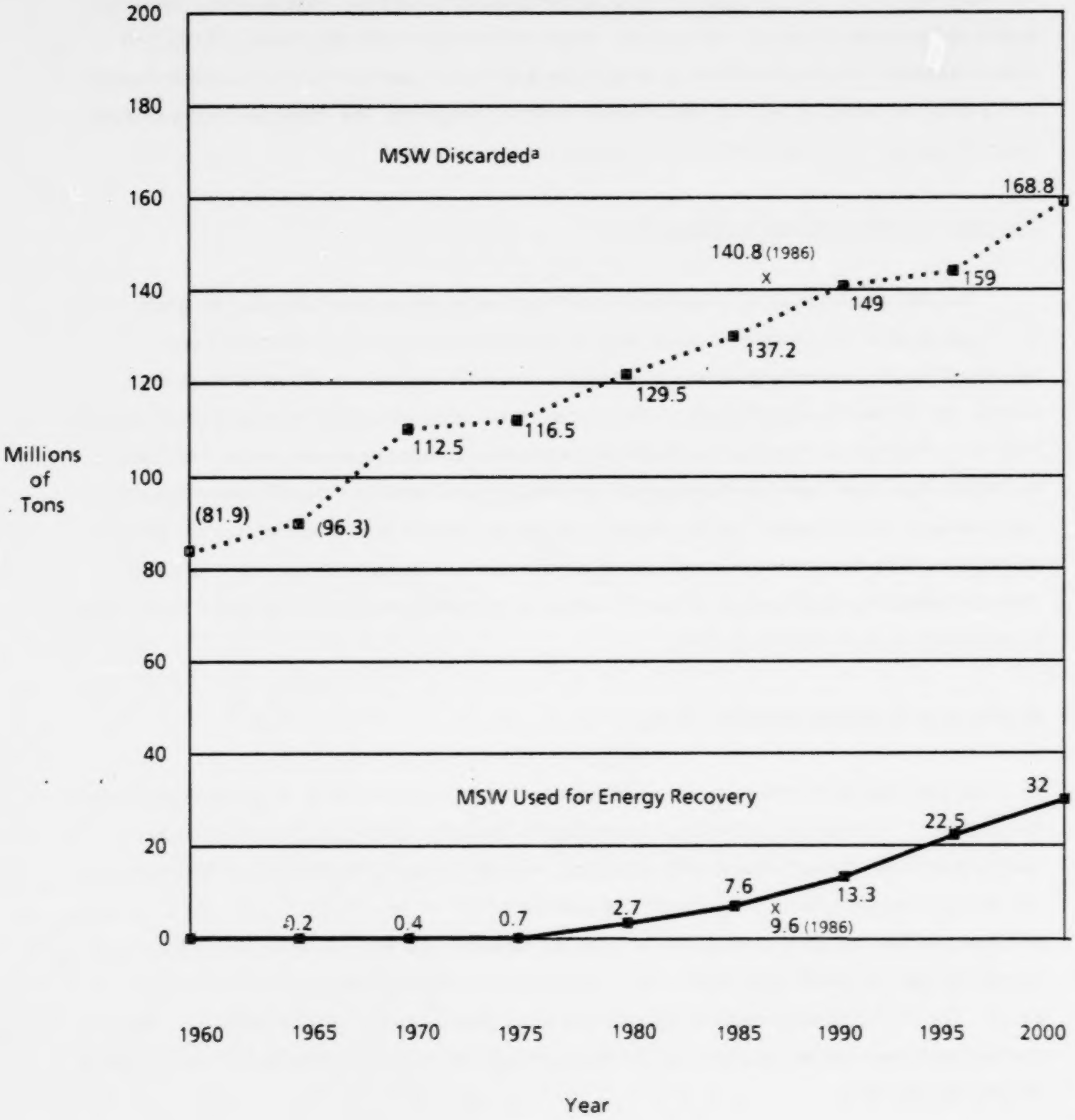
The MSW characterization study reports that about 158 million tons of MSW were produced in 1986 and 141 million tons (89 percent) were discarded. The amount discarded is equivalent to approximately three pounds per capita per day (pcd). The study also presents estimates of the amount of municipal waste discarded (in millions of tons per year) from the period 1960 to 2000. These estimates are presented in Figure 3-1. According to the characterization study, MSW discarded in the year 2000 is projected to be twice that discarded in 1960.

Management Practices for Municipal Solid Waste

Options available for the management of MSW include land disposal, ocean disposal, incineration with or without energy recovery, and recovery of materials. The characterization study addresses three of the MSW management alternatives: municipal landfills, incineration with energy recovery, and materials recovery. The report estimates that of the total 157.7 million tons of MSW produced, 9.6 million tons per year (6.0 percent) were used for energy recovery in 1986, and 131.2 million tons (83.2 percent) were managed through landfills, ocean disposal, or incineration without energy recovery. Since the amounts of waste being disposed of by ocean disposal and incineration without energy recovery are considered negligible relative to landfill disposal, 131.2 million tons can be accepted as an upper-bound estimate of MSW disposed of in landfills in 1986. The remaining estimated 16.9 million tons (10.7 percent) of MSW were recovered for materials.[1,4].

The percentage of MSW recovered for materials is expected to increase as more States incorporate recycling into their solid waste management plans. It has been estimated that 25-30 percent of MSW is easily recyclable.[6] Most of the recovery to date has been accomplished through source separation (i.e., when the waste generator separates recyclable wastes from other wastes).[7,8] There are approximately 400-500 curbside recycling programs[9] and an estimated 30-40 centralized materials separation facilities in the United States.[10] The characterization study estimates that recovery rates in 1984 for aluminum, glass, and paper were 40, 7, and 21 percent, respectively. Recycling of municipal waste is the subject of another Report to Congress prepared by EPA in conjunction with a study of municipal waste combustion (i.e., energy recovery).[6]

Figure 3-1. MUNICIPAL SOLID WASTE DISCARDED AND ENERGY RECOVERY FROM MUNICIPAL SOLID WASTE, 1960 - 2000



SOURCE: References 1 and 4.

[a] After materials recovery has taken place.

3.2 HOUSEHOLD HAZARDOUS WASTE

Household hazardous waste (HHW) is waste generated by households that meets the RCRA technical definition of a hazardous waste but is exempted from Subtitle C regulations. "Household" is defined here as any type of living quarters: single and multiple dwellings, hotels, motels, and other residences. Household hazardous waste is generally discarded directly into the MSW stream, with a small fraction diverted into special HHW collection programs. The characteristics, quantities, and management practices for HHW are discussed separately, below.

Characteristics of Household Hazardous Waste

According to A Survey of Household Hazardous Wastes and Related Collection Programs,[2] HHW is generated by disposal of products such as those listed in Exhibit 3-1. Exhibit 3-1 was developed by scanning the ingredients listed on the label's of household products for hazardous compounds. Where household products did not have labels that stated the chemical ingredients and their concentrations, professional estimates of the chemical compositions were made. Included in this list are keys to the chemical characteristic responsible for a hazardous classification. Household items that are keyed as being "Listed" contain compounds that are toxic or acutely toxic. Table 3-2 presents the hazardous chemical constituents found in common household products. Because HHW contains these hazardous constituents, users (e.g., homeowners) may be harmed if they misuse or improperly store or dispose of HHW.

Quantities of Household Hazardous Waste

Several local government studies were reviewed to obtain information on quantities of HHW. Two studies [11, 12] conducted by the Los Angeles County Sanitation District involved sorting and weighing of MSW. One of these studies estimated that the fraction of HHW in the MSW stream was less than 0.2 percent by weight; the other study estimated 0.0015 percent by weight. The University of Arizona conducted HHW surveys in New Orleans, Louisiana, and Marin County, California,[13] and found that the fraction of HHW in the MSW stream was approximately 0.35 to 0.40 percent by weight. The MSW characterization study estimate of 141 million tons of MSW discarded in 1986 and the results of these studies were used by EPA to estimate a national HHW generation rate of 2,000 to 560,000 tons per year.

The annual generation rates of the different products composing HHW were estimated in the study conducted by the University of Arizona[13] and in another study conducted in King County,

Exhibit 3-1. HOUSEHOLD HAZARDOUS WASTES AND THEIR CHARACTERISTICS

- Automotive Products
  - Air conditioning refrigerants (Listed)
  - Body putty (I)
  - Carburetor and fuel injection cleaners (I)
  - General lubricating fluids (I or E)
  - Grease and rust solvents (I)
  - Oil and fuel additives (I)
  - Radiator fluids and additives (I)
  - Starter fluids (I or Listed)
  - Transmission additives (I)
  - Waxes, polishes, and cleaners (I or C)
- Home Maintenance Products
  - Adhesives (I)
  - Paints (I)
  - Paint strippers and removers (I)
  - Paint thinners (I)
  - Stains, varnishes, and sealants (I)
- Household Cleaners
  - Disinfectants (C or I)
  - Drain openers (C)
  - General purpose cleaners (C or I)
  - Oven cleaners (C)
  - Toilet bowl cleaners (C)
  - Wood and metal cleaners and polishes (I)
- Lawn and Garden Products
  - Fungicides or wood preservatives (Listed)
  - Herbicides (E or Listed)
  - Pesticides (E or LIsted)
- Miscellaneous
  - Batteries (C or E)
  - Electronic items (E)
  - Fingernail polish remover (I)
  - Photo processing chemicals (E, C, or I)
  - Pool chemicals (R)

SOURCE: Reference 2.

C: Corrosive
I: Ignitable
Listed: Toxic or acutely toxic
E: EP toxic
R: Reactive

Table 3-2. HAZARDOUS CONSTITUENTS OF COMMON HOUSEHOLD COMMODITIES

Item	Known Examples of Hazardous Ingredients
Automotive Maintenance	
Antifreeze/coolant	Ethylene glycol Methanol
Auto wax	Petroleum distillates
Engine treatment (transmission and motor oil additives; fuel additives, carburetor cleaner, etc.)	Methylene chloride Mineral spirits Petroleum distillates Toluene 1,1,2-Trichloroethylene Xylenes
Oil and transmission fluid (grease, hydraulic fluid, motor oil, all purpose oil, etc.)	Lead Petroleum distillates (petroleum hydrocarbons)
Other auto (grease solvents, rust solvents, refrigerants, etc.)	Chlorinated aliphatic hydrocarbons Potassium dichromate Toluene
Batteries and Electrical	
Auto and flashlight batteries, solder, etc.	Mercuric oxide Sulfuric acid
Household Cleaners	
Air freshener	Alkyl phenoxy polyethoxy ethanol Isobutane Propane
Ammonia based cleaner	Ammonia Ammonium hydroxide Diethylene glycol Ethoxylated alcohol Phenols Sodium hypochlorite Surfactants Xylenols
Drain opener	Hydrochloric acid Potassium hydroxide Sodium hydroxide Sodium hypochlorite Trichlorobenzene Trichloroethane
Floor finish	Ammonia Diethylene glycol Petroleum solvents

Table 3-2. (continued)

Item	Known Examples of Hazardous Ingredients
Laundry soap, bleach, dish-washing detergent, bathroom cleaners, upholstery cleaners, floor cleaners, other general purpose cleaners	Ethylene glycol Methanol chloride Perchloroethane Sodium hypochlorite Surfactants Tetrachloroethylene
Polish (furniture, wood, metal, vinyl, etc.)	Denatured ethanol or isopropanol Mineral spirits Oxalic acid Petroleum distillates Petroleum solvents Phosphoric acid 1,1,1-Trichloroethane
Toilet bowl cleaner	Chlorinated phenols Sodium acid sulfate or oxalate or hydrochloric acid Trichloro-s-triazinetrione
Other household cleaners (oven cleaner, etc.)	Sodium or potassium hydroxide
Household Maintenance	
Glue (model, epoxy, general purpose, etc.)	Acetone Asbestos fiber (asbestos cement) Hexane Methylene chloride Methyl ethyl ketone Toluene
Paint (latex, oil base, art and model paints, etc.)	Halogenated aromatic hydrocarbons Methylene chloride Mineral spirits Toluene Xylene
Paint thinner and stripper (remover)	Alcohols Chlorinated aliphatic hydrocarbons Chlorinated aromatic hydrocarbons Esters Ketones Toluene
Stain/varnish/sealant	Benzene Lead Methyl and ethyl alcohol Methylene chloride Mineral spirits Pentachlorophenols Petroleum

Table 3-2. (continued)

Item	Known Examples of Hazardous Ingredients
Other maintenance (asphalt caulking, tar paper, etc.)	Asbestos Benzene Ketones Methylene chloride Toluene Trichloroethylene
Pesticide and Yard Maintenance	
Fertilizer	Concentrated potassium, ammonia, nitrogen, phosphorus
Herbicides	Chlorinated phenoxys Dipyridyl Nitrophenols
Pesticides	Aromatic petroleum hydrocarbons Carbamates Chlorinated hydrocarbons Coumarin Naphthalene Organophosphorus Petroleum distillates Triazine base Uracil Urea Xylene
Pet maintenance (flea and tick treatment powders and liquids, flea and tick collars, etc.)	Carbaryl Chlordane Dichlorophene Other chlorinated hydrocarbons
Prescription Drugs	Diverse ingredients
Selected Cosmetics	
Nail polish remover, hairspray, make-up remover, dyes, etc.	Acetone Alcohols Aromatic hydrocarbon solvents Dibutyl phthalate Ethyl and butyl acetate Toluene
Other	
Pool chemicals (acid, chlorine) Hobby related activities, etc.	Sodium dichloro-s-triazinetrione

SOURCE: Reference 14.

Washington.[14] Automotive oil, paints, and batteries accounted for more than 50 percent of the HHW in both Marin County, California, and New Orleans, Louisiana. The results of the University of Arizona Study are summarized in Table 3-3. In the King County study, residential and self-haul wastes were sampled in order to quantitatively assess the characteristics of HHW. Residential waste contained large amounts of cleaners, paints, oils, and batteries. Self-haul wastes contained banned pesticides, solvents, and paints. The large quantities of hazardous wastes found in the self-haul waste stream may have been the result of garage and basement cleaning. The results of the King County study are presented in Table 3-4. A fourth study,[15] conducted in Albuquerque, New Mexico, employed a questionnaire to determine how much hazardous waste a sample group of household members could recall discarding. Results from this study are limited in validity because respondents may have based their answers on incorrect perceptions of hazardous materials. This study did not contain data on the proportion, by weight, of HHW in the MSW stream.

Management Practices for Household Hazardous Waste

The volume of HHW managed by various disposal options is unknown. The major management options exercised by the public are disposal with MSW and disposal into municipal sewer systems and septic tanks. As mentioned previously, the portion of HHW collected by special programs is small; however, HHW collection programs are increasing in number.

In the last six years, more than 530 locally sponsored HHW collection programs have been held. Most of these collection programs have been one-day special events, but more permanent programs are being established. Collection programs provide many benefits beyond the collection and disposal of HHW. Education of the public and increased awareness of the presence of hazardous materials in the home are assets of these programs. The EPA has compiled a bibliography of HHW information and a list of expert contacts for each State.[16]

3.3 MUNICIPAL SLUDGE

Municipal sludge includes both drinking water and wastewater (sewage) treatment sludges. The EPA Office of Water Regulations and Standards (OWRS) maintains a data base[17] on publicly owned treatment works (POTWs), which includes data on municipal sewage sludge characteristics, generation, and disposal. The MSW characterization study supplies additional data in these areas for sewage and water treatment sludge, and the American Water Works Association (AWWA) provides data on quantities of water treatment sludge generated.[18]

Table 3-3. ANNUAL GENERATION RATES OF HOUSEHOLD HAZARDOUS WASTE IN NEW ORLEANS, LOUISIANA, AND MARIN COUNTY, CALIFORNIA

Waste Type	Projected Annual Generation Rate in Locality (tons/year)		Percent of Total	
	New Orleans	Marin County	New Orleans	Marin County
Automotive Maintenance				
Antifreeze/coolant	10.6	0.0	1.5	0.0
Auto wax	1.6	2.6	0.2	0.9
Engine treatment	0.6	3.6	0.1	1.3
Oil	133.3	23.1	18.9	8.1
Transmission fluid	0.0	0.6	0.0	0.2
Other auto	3.3	3.2	0.5	1.1
Subtotal	149.4	33.1	21.2	11.6
Batteries and Electrical	84.0	76.0	11.9	26.6
Household Cleaners				
Air freshener	0.4	1.9	0.1	0.7
Ammonia-based cleaners	0.1	2.3	0.0	0.8
Bleach	0.9	0.3	0.1	0.1
Cleaner	7.7	18.0	1.1	6.3
Dish detergent	3.6	3.1	0.5	1.1
Drain opener	0.1	0.0	0.0	0.0
Floor finish	2.4	2.0	0.3	0.7
Laundry soap	52.0	3.7	7.4	1.3
Polish	17.3	4.6	2.5	1.6
Toilet bowl cleaner	0.0	2.3	0.0	0.8
Other household	8.6	4.7	1.2	1.6
Subtotal	93.1	42.9	13.2	15.0
Household Maintenance				
Glue	14.4	4.7	2.0	1.7
Paint	132.8	26.8	18.8	9.4
Paint thinner	0.0	0.8	0.0	0.3
Stain/varnish	20.2	7.0	2.9	2.5

Table 3-3. (continued)

Waste Type	Projected Annual Generation Rate in Locality (tons/year)		Percent of Total	
	New Orleans	Marin County	New Orleans	Marin County
Other maintenance	139.2	39.9	19.7	13.9
Subtotal	306.6	79.2	43.4	27.8
Pesticides and Yard Maintenance				
Fertilizers	0.0	3.5	0.0	1.3
Herbicides	0.0	0.0	0.0	0.0
Pet maintenance	2.0	4.1	0.3	1.4
Pesticides	4.8	17.5	0.7	6.1
Subtotal	6.8	25.1	1.0	8.8
Prescription drugs	7.5	9.1	1.1	3.2
Selected cosmetics	35.1	10.8	5.0	3.8
Other				
Hobby related	2.3	5.1	0.3	1.8
Miscellaneous	21.8	3.8	3.1	1.4
Subtotal	24.1	8.9	3.4	3.2
Total[a]	706.6	285.1	100	100

SOURCE: Reference 13.

[a] Percentages are rounded and may not total 100 percent.

Table 3-4. POTENTIALLY HAZARDOUS WASTES IN KING COUNTY MUNICIPAL SOLID WASTE

Waste Category	Residential Waste[a] (tons/yr)	Self-Haul Waste[b] (tons/yr)	Total (tons/yr)
Cleaners	297.9	98.9	396.8
Solvents	14.7	490.1	504.8
Paints	254.6	2,877.5	3,132.1
Oils	347.6	39.2	386.8
Acids	2.9	0.0	2.9
Bases	8.3	35.1	43.4
Pesticides	19.3	98.6	117.9
Aerosols	18.0	49.3	67.3
Batteries	220.7	311.3	532.0
Cosmetics	81.1	15.7	96.8
Medicine	33.3	2.0	35.3
Alcohols	15.9	1.4	17.3
Waxes	14.8	52.1	66.9
Adhesives	18.5	493.1	511.6
Inks	5.1	6.4	11.5
Total	1,352.7	4,570.7	5,923.4

SOURCE: Reference 14.

[a] Residential waste is defined here as waste collected by regular route collection from private residences.

[b] Self-haul waste is defined here as waste hauled in cars and small trucks to a waste management facility by small contractors and members of the general public. Note that self-haul waste may include industrial as well as household hazardous waste.

Wastewater Treatment Sludge

Biological processes are predominantly used for municipal sewage treatment. They result in sludge that consists primarily of organic matter. If either aerobic or anaerobic sludge digestion is used, the organic fraction of the sludge solids may be reduced by approximately 50 percent. The OWRS has used a data base of 15,300 POTWs to estimate that 6.9 million dry tons of sewage sludge are generated each year.[17] This data base also shows that sewage sludge is managed through incineration (20 percent), land application (25 percent, including 6.0 percent that is distributed and marketed), ocean disposal (6 percent), and lagooning and landfilling (49 percent, including 1.0 percent in monofills, landfills that receive only sewage sludge). Incineration produces a residue consisting primarily of an inorganic ash. This residue quantity is usually much smaller, by weight, than the original sludge and is often landfilled.

Water Treatment Sludge

Drinking water treatment processes--including coagulation/filtration, direct filtration, lime softening, and greensand filtration--produce sludge that consists of a variety of organic and inorganic materials. The concentration of contaminants in the sludge depends on the treatment process chosen and the quality of the raw water. The AWWA conducted a survey of drinking water treatment utilities serving populations greater than 25,000. It estimated that these utilities generate 80 percent of the drinking water treatment sludge produced in the nation.[18] Of the 1,290 utilities surveyed, 637 (49 percent) responded. Based on these data, 3.5 million tons of drinking water treatment sludge may be generated each year. Drinking water treatment sludge may be discharged to a sanitary sewer, applied to the land, landfilled, stored on the site in a lagoon, or subjected to chemical recovery and treatment techniques.

3.4 MUNICIPAL WASTE COMBUSTION ASH

There are three categories of MSW fuel combustion: raw MSW; refuse-derived fuel (RDF), which is processed MSW; and co-firing a varying amount of refuse-derived fuel or MSW with coal, oil, wood, sewage sludge, or other fuel.[19] Approximately 6 percent of all MSW generated is incinerated at energy-recovery facilities.[1,4] There are approximately 140 municipal waste combustion (MWC) facilities operating in the United States with a total capacity of 62,000 tons of waste per day. There are an additional 210 facilities in various stages of planning and construction. By the year 2000, 350 facilities are expected to be on line, with a capacity of 250,000 tons per day.[20]

Characteristics of Municipal Waste Combustion Ash

Fly ash and bottom ash are generated from the combustion process. Fly ash is captured in the stack by emissions control equipment, bottom ash is the residue from burning that remains in the combustion chamber.

The incineration of MSW fuel is a process that can differ greatly from plant to plant and from one geographic area to the next.[19] Consequently, the characteristics of the MWC solid residues can differ greatly. For example, RDF facilities that shred the municipal waste and/or remove metals prior to combustion generally produce MWC ash with lower concentrations of some organics and inorganics than those that do not shred the waste or remove metals. Ash characteristics also depend on facility operational parameters and facility design including air pollution control equipment.

Tests done on leachate from monofills containing MWC residues have also shown heavy metals, particularly lead which has exceeded the primary and secondary drinking water standards.[19,21,22,23] The results from the tests discussed above indicate that at some facilities there is a potential for polluting the environment with heavy metals and mineral salts from MWC residues, unless the disposal facility is designed to eliminate the potential hazard.

The Extraction Procedure (EP) toxicity tests conducted on fly ash and bottom ash from various municipal waste incinerators have shown that these residues have highly variable concentrations of heavy metals, particularly lead and cadmium.[19, 24] Some of these residues, particularly fly ash, may have high metal concentrations. Other tests have shown the presence of the following organics in low concentrations: polychlorinated dibenzodioxin (PCDDs), polychlorinated dibenzofuran (PCDFs), and polychlorinated biphenyls (PCBs) with higher concentrations in fly ash than bottom ash. The levels of PCDDs and PCDFs have been linked to combuster parameters.

Quantities of Municipal Waste Combustion Ash

Combustion reduces the MSW volume by 70 to 90 percent and the mass by 50 to 80 percent. The quantity of ash depends on the moisture content of the incoming waste and on whether the MSW is shredded prior to combustion. Using the approximation of total capacity discussed above, EPA estimates that in 1988, 3.2 to 8.1 million tons of ash will be generated. This amount is expected to increase to 17 million tons in the year 2000. Fly ash ranges from 5 to 8 percent of the total ash depending on operational parameters.

Some additional tonnage is generated from MSW incinerators not practicing energy recovery and from those establishments that burn their own waste. Incinerator residue from this latter category is probably included in estimates of industrial process wastes or other industrial wastes.

Management of Municipal Waste Combustion Ash

Approximately 90 percent of the MWC solid residues is being disposed of in MSW landfills and MWC residue monofills. To a much lesser degree, MWC solid residues are being used for cover material, road construction, cement/concrete mixtures, and other uses. In 36 States, ash is co-disposed with other waste. In 19 States, ash disposal is addressed through statutes, regulations, or permits.

It should be noted that EPA has conducted a comprehensive municipal waste combustion ash characterization study[25] and is evaluating appropriate management methods.

3.5 INFECTIOUS WASTE

There is no universally accepted definition for infectious waste. The EPA Guide for Infectious Waste Management[26] defines infectious waste as waste capable of producing an infectious disease. Although infectious waste is not generated just by hospitals (i.e., doctors' offices, nursing homes, etc. also contribute to the waste stream), the only quantitative data available are for infectious hospital waste. In 1985, there were 6,862 hospitals in the U.S. with 1,318,000 beds. It is estimated that 8 to 13 pounds of infectious wastes are generated per bed each day. Using the high end of this range and a 69 percent occupancy rate, the total hospital waste generation is estimated at 5,900 tons per day or more than 2 .1 million tons per year.[27]

EPA has categorized infectious waste into the following six groups:

- isolation wastes,
- cultures and stocks of infectious agents and associated biologicals,
- human blood and blood products,
- pathological wastes,
- contaminated sharps (needles, etc.), and
- contaminated animal carcasses, body parts, and bedding.

Infectious waste may be treated so that it is no longer biologically hazardous, and disposed of as nonhazardous solid waste, provided the waste poses no other hazards that are subject to Federal or State regulations.[26] Treated liquid wastes are usually disposed of directly to the sanitary sewer system, if approved by the local authority. Treated solid wastes and incinerator ash are usually disposed of in sanitary landfills. A recent survey conducted by the National Solid Wastes Management Association found that 28 States and the District of Columbia have some special management requirements for infectious wastes, 31 States require treatment to render the waste noninfectious, and five States regulate infectious wastes as hazardous wastes.[28] The volumes of infectious wastes managed by various disposal options are unknown.

3.6 TIRES

The Department of Energy (DOE) conducted a study[29] to assess the potential of recovering energy from scrap tires. It investigated tire stockpiles within 100 to 150 miles of any major metropolitan area that contained at least 100,000 tires. More than 34 stockpiles were identified that met these criteria, although many more smaller ones exist. From this number, DOE determined that approximately 240 million automobile and truck tires are discarded annually in the United States.

Management of Scrap Tires

The results of this study indicated that less than 20 percent of the 240 million tires discarded per year are recovered for recapping or resale, and only about 10 percent are reclaimed: rubber reclaiming (5 percent); energy recovery (about 3 percent); splitting (1 percent); and use in artificial reefs, highway crash barriers, highway base materials, and children's playthings (less than 1 percent). The other 70+ percent of discarded tires (approximately 168 million per year) are disposed of in landfills or junkyards as scrap tires.

Because tires have a high energy value of approximately 15,000 Btu/pound,[29] the DOE study was conducted to investigate alternatives for alleviating the scrap tire problem by converting the waste product into energy. It focused on tire pyrolysis technologies and found it was a mature and well-developed technology. In a recent study[30] conducted for DOE, however, it was found that no pyrolysis process proposed to date in the United States has proven economically feasible. This recent study focused on controlled combustion of tires, specifically incineration of tires in a free-standing new power plant and in cement kilns.

Recent studies and articles[29,31,32,33,34] suggest that interest in tire recycling has grown in the past several years. The primary techniques being studied are cryogenic grinding, shredding and incineration, and adding to asphalt.[30,31] Using shredded tires, instead of wood chips, as a bulking agent for composting sewage sludge has also been studied.[34]

Characteristics of Scrap Tires

Scrap tires placed in landfills can present health, safety, environmental, and handling problems. These tires provide an excellent breeding ground for vermin and mosquitoes, do not biochemically degrade completely when buried, and resurface in landfills if not anchored. Because of their shape, tires stored outdoors collect and hold rain water. Leaves, grass, and other nutrients falling into the tires provide an ideal habitat for immature mosquitoes.[35] The dark tires absorb heat efficiently, providing warmth for rapid insect development. In the United States, at least four species of tire-breeding mosquitoes transmit diseases to humans and domestic animals.[36] Aedes aegypti and Aede triseriatus transmit the viruses that cause dengue fever and LaCrosse encephalitis, respectively, while the recently introduced Aedes albopietus can transmit both viruses. Culex pipiens is a vector of St. Louis encephalitis virus, and all of these species are able to transmit dog heartworm.

3.7 INDUSTRIAL NONHAZARDOUS WASTE

The two sources of data on industrial Subtitle D waste are the Industrial Facilities Survey[37] and the Summary of Data on Industrial Nonhazardous Waste Disposal Practices.[38] The first is a survey of 17 major industries. It provides data on the number of Subtitle D units these industries have on the site and the waste quantities disposed of in them. The second study presents data on 22 major industries (encompassing all but one of the 17 industries surveyed) and includes a review of compiled available data on industrial nonhazardous waste characteristics and generation rates. The limitations of the Industrial Nonhazardous Waste Disposal Study are discussed in Chapter 2. The characteristics, quantities, and management methods for industrial Subtitle D waste are discussed below.

Characteristics of Industrial Nonhazardous Waste

The characteristics of industrial nonhazardous waste vary from industry to industry and within each industry. The major waste types within each of the 22 industries[38,39] and the general waste characteristics for each industry with regard to the relative concentration of heavy metals or organics are presented in Tables B-1 and B-2 (Appendix B), respectively. Twelve of the 22 industries studied are expected to contain relatively high levels of heavy metals and organic constituents, five industries contain relatively moderate levels, and the remaining five industries contain low levels.

Included in these waste streams are some PCB-contaminated wastes. The Toxic Substances Control Act (TSCA) PCB disposal regulations allow limited categories of PCB materials to be disposed of in Subtitle D landfills. These materials include drained PCB-contaminated electric equipment that contained 50-500 ppm PCBs in dielectric fluids, drained hydraulic and heat transfer equipment, and "PCB Articles" (see 40 CFR Sections 761.3 and 761.60(b)(5)) that previously contained 50-500 ppm PCBs and that have been drained of free-flowing liquids. More significantly, TSCA disposal regulations allow the disposal of "small capacitors" that contain less than three pounds of PCB dielectric in Subtitle D landfills. These small capacitors frequently are found in fluorescent light ballasts, high-intensity discharge lighting power supplies, and a variety of consumer appliances, such as microwave ovens and air conditioners.

In addition, regulations under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) allow pesticide containers that have been properly rinsed in accordance with the label instructions to be disposed of in Subtitle D landfills.

Quantities of Industrial Nonhazardous Waste

The quantity of industrial waste disposed of in on-site Subtitle D units for the 17 industries covered in the facilities survey is presented in Table 3-5. The 17 industries studied dispose of approximately 7.6 billion tons of industrial nonhazardous waste on-site each year. Nearly 95 percent of the waste is produced by 10 industries. The top two industries, pulp and paper and primary iron and steel, produce 47 percent of the waste. Table B-1 (Appendix B) presents the generation rates estimated in the Industrial Nonhazardous Waste Disposal Study for the 22 industries studied. The quantities estimated in this study are much lower than quantities estimated from the survey. Reasons for this large discrepancy are being investigated. At this time, the survey data are considered more accurate because, for the industrial nonhazardous waste disposal study, waste quantity information was not available for all industries, and the data that were available were often more than five years old.

Management Practices for Industrial Nonhazardous Waste

The Industrial Facilities Survey indicates that 2,757 landfills, 15,253 surface impoundments (SIs), 4,308 land application units (LAUs), and 5,335 waste piles received industrial nonhazardous waste. The percent of the waste stream that went to each on-site unit is presented in Table 3-5. Most of the waste is managed in surface impoundments. The amount of waste that is recycled or is disposed of off-site is not known.

3.8 VERY-SMALL-QUANTITY GENERATOR WASTE

Small-quantity generator (SQG) waste is waste that meets the definition of a hazardous waste under 40 CFR Part 261 and is generated at a rate of less than 1,000 kilograms per month. While SQG waste has been exempt from Subtitle C regulations, a March 24, 1986, rule applies certain Subtitle C regulations to SQGs generating between 100 and 1,000 kilograms per month.[40] This rule took effect on September 22, 1986, for off-site and September 22, 1987, for on-site treatment, storage, or disposal. After these effective dates, the exemption from Subtitle C regulations applies only to generators of less than 100 kilograms per month of hazardous waste. These very-small-quantity generators (VSQGs) are regulated under Subtitle D of RCRA.

The National Hazardous Waste Small Quantity Generator Survey[41] is the principal source of data on SQG waste. Through a mail questionnaire, the survey obtained national estimates of the number and type of SQGs and their waste generation and management practices. The detailed results of the survey address 22 primary industries and 27 targeted wastes, accounting for 378,000 (60 percent) of the estimated 630,000 generators and approximately 658,000 (64 percent) of the estimated 1,036,000 tons of SQG hazardous waste generated annually. Results distinguish between SQGs of 100 to 1,000 kilograms per month of hazardous waste (now regulated under Subtitle C) and VSQGs of less than 100 kilograms per month (regulated under Subtitle D). A discussion of the hazardous waste produced by SQGs of 100 to 1,000 kilograms per month is included here because it has only recently been considered a Subtitle C waste.

Three smaller-scaled surveys[42,43,44] on small-quantity generators of hazardous waste were conducted in the cities of Hampton, Richmond, and Lynchburg, Virginia; the counties of Chesterfield and Henrico, Virginia; the Puget Sound area in the State of Washington; and the State of Delaware. The purpose of these surveys was to:

- inform small businesses of the pending regulation of businesses that generate between 100 and 1,000 kg/month of hazardous waste,
- assist the small businesses to comply with the new regulations, and
- survey current waste management practices of small businesses.[45]

Table 3-5. WASTE QUANTITY DISPOSED OF IN ON-SITE INDUSTRIAL FACILITIES IN 1985[a]

Industry Type	Total Waste Quantity Disposed of in All On-Site Industrial Facilities (thousand tons)	Percent of Waste Disposed of in Landfills[a]	Percent of Waste Disposed of in Surface Impoundments	Percent of Waste Disposed of in Land Application Units	Percent of Waste Disposed of in Waste Piles
Organic Chemicals	58,864	0.4	96.3	3.1	0.08
Primary Iron and Steel	1,300,541	0.3	99.2	<0.01	0.5
Fertilizer and Agricultural Chemicals	165,623	3.5	93.1	0.5	2.9
Electric Power Generation	1,092,277	4.9	95.0	0.03	0.08
Plastics and Resins Manufacturing	180,510	0.05	98.2	0.02	1.7
Inorganic Chemicals	919,725	0.4	95.1	0.01	4.5
Stone, Clay, Glass, and Concrete	621,974	1.2	97.3	<0.01	1.5
Pulp and Paper	2,251,700	0.3	99.3	0.4	0.07
Primary Nonferrous Metals	67,070	2.1	84.3	0.6	13
Food and Kindred Products	373,517	1.0	78.6	20	0.1
Water Treatment	58,846	0.3	84.5	15	0.1
Petroleum Refining	168,632	0.2	99.6	0.2	0.05
Rubber and Miscellaneous Products	24,198	2.2	97.4	0.2	0.2
Transportation Equipment	12,669	1.4	93.1	<0.01	4.6
Selected Chemical and Allied Products	67,987	0.2	99.1	0.7	0.01
Textile Manufacturing	253,780	0.03	99.7	0.3	<0.01
Leather and Leather Products	3,234	0.3	99.4	0	0.3
Total	7,616,149	1.1	96.6	1.3	1.0

SOURCE: Reference 37.

[a] Percentages are rounded and do not total 100 percent.

Additional information on the types and amounts of SQG hazardous wastes is available from an extensive survey of SQGs and municipal solid waste landfills (MSWLFs) in Florida.[46] These data also include some hazardous waste quantities from large-quantity generators.

Characteristics of Small-Quantity-Generator Waste

The SQG hazardous waste streams in the industries addressed in the SQG survey are presented in Table 3-6. This table indicates that used lead-acid batteries represent the largest hazardous waste quantity and the largest number of generators, in both the VSQG and other SQG categories. Other significant hazardous wastes are spent solvents, dry cleaning filtration residues, and photographic wastes.

There are an estimated 600,000 to 660,000 SQGs of hazardous waste in the United States representing 98 percent of the total number of hazardous waste generators.[41] Nearly 85 percent of SQGs are in nonmanufacturing industries, including 50 percent in vehicle maintenance and 10 percent in construction. Other nonmanufacturing establishments include laundries, photographic processors, equipment repair shops, laboratories, and schools. The remaining 15 percent of SQGs are manufacturing establishments, with two-thirds of these in metal manufacturing and the remaining generators in manufacturing industries, such as printing, chemical manufacturing, and textile manufacturing.[41] Table 3-7 presents the number of SQGs in each industry group.

Very-small-quantity generators constitute 70 percent of the SQGs, and the industrial distribution of VSQGs differs from that of other SQGs. Most of the VSQGs are in nonmanufacturing industries, whereas relatively few of the other SQGs are found in this category. In contrast, there is a more even distribution between VSQGs and other SQGs in the manufacturing industries.

Quantities of Small-Quantity Generator Waste

Small-quantity generators are estimated to generate about 1,036,000 tons of hazardous waste annually, which is 0.5 percent of the total quantity of hazardous waste.[41] Very-small-quantity generators produce about one-fifth of all SQG hazardous waste. Approximately 658,700 tons of hazardous waste are generated by the 22 primary industry groups studied in the SQG survey. Sixty-two percent (408,000 tons per year) of this waste is used lead-acid batteries; 18 percent (116,000 tons per year) is solvents; and 5 percent (33,000 tons per year) is acids and alkalies. Table 3-6 presents the breakdown of SQG waste quantity according to various types of waste streams.[41] Vehicle

Table 3-6. NUMBER OF SMALL-QUANTITY GENERATORS AND WASTE QUANTITY GENERATED BY WASTE STREAM

Waste Stream[a]	VSQGs: Generators of < 100 kg of Hazardous Waste/Month [Subtitle D Waste]		Other SQGs: Generators of 100 kg to 1,000 kg of Hazardous Waste/Month [Subtitle C Waste]	
	Number of Generators	Waste Quantity (tons/yr)	Number of Generators	Waste Quantity (tons/yr)
Arsenic wastes	21	8	19	114
Cyanide wastes	587	19	1,384	2,345
Dry cleaning filtration residues	13,168	5,674	2,540	9,373
Empty pesticide containers	9,809	1,424	1,963	2,606
Heavy metal dust	48	11	40	180
Heavy metal solutions	15	7	30	57
Heavy metal waste materials	121	34	117	592
Ignitable paint wastes	12,788	2,028	3,122	5,367
Ignitable wastes	8,951	1,001	2,873	8,345
Ink sludges containing chromium or lead	1,093	99	83	140
Mercury wastes	19	1	0	0
Other reactive wastes	1,133	97	497	1,201
Paint wastes containing heavy metals	381	13	156	8
Pesticide solutions	3,207	1,153	1,747	5,532
Photographic wastes	21,287	4,856	4,949	15,447
Solutions of sludges containing silver	4,482	1,033	2,648	8,792
Solvent still bottoms	2,114	126	738	2,052
Spent plating wastes	3,960	543	1,422	5,811
Spent solvents	77,629	21,420	33,475	94,650
Strong acids or alkalies	13,739	2,170	10,480	30,647
Used lead-acid batteries	119,747	71,495	77,880	335,089
Waste formaldehyde	11,930	3,805	2,014	5,944

Table 3-6. (continued)

Waste Stream[a]	VSQGs: Generators of < 100 kg of Hazardous Waste/Month [Subtitle D Waste]		Other SQGs: Generators of 100 kg to 1,000 kg of Hazardous Waste/Month [Subtitle C Waste]	
	Number of Generators	Waste Quantity (tons/yr)	Number of Generators	Waste Quantity (tons/yr)
Waste inks containing flammable solvents or heavy metals	3,642	290	718	1,497
Waste pesticides	2,852	441	990	944
Wastes containing ammonia	1,154	106	100	298
Wastewater containing wood	88	29	108	763
Wastewater sludges containing heavy metals	894	207	790	2,441
Total	314,679	118,090	150,883	540,235

SOURCE: Reference 41.

[a] Some SQGs generate more than one waste stream.

Table 3-7. NUMBER OF SMALL-QUANTITY GENERATORS BY INDUSTRY GROUP

Industry	VSQGs: Generators of <100 kg of Hazardous Waste/Month [Subtitle D Waste]		Other SQGs: Generators of 100 kg to 1,000 kg of Hazardous Waste/Month [Subtitle C Waste]	
	Number of Generators Per Industrial Category	Percent of Generators Per Industrial Category	Number of Generators Per Industrial Category	Percent of Generators Per Industrial Category
Analytical and clinical laboratories	5,123	80	1,286	20
Chemical manufacturing	362	48	391	52
Cleaning agents and cosmetic manufacturing	277	51	265	49
Construction	11,561	91	1,117	9
Educational and vocational establishments	3,239	93	241	7
Equipment repair	1,526	85	269	15
Formulators	507	57	395	43
Furniture/wood manufacture and refinishing	2,776	83	579	17
Laundries	13,131	84	2,515	16
Metal manufacturing	26,245	70	11,076	30
Motor freight terminals	103	70	45	30
Paper industry	98	54	83	46
Pesticide application services	7,786	82	1,660	18
Pesticide end users	1,392	86	231	14
Photography	6,538	70	2,817	30
Printing/ceramics	21,190	86	3,450	14
Textile manufacturing	149	54	124	46
Vehicle maintenance	142,105	63	82,528	37
Wholesale and retail establishments	5,156	90	575	10
Wood preserving	86	45	107	55
Other manufacturing	1,618	63	946	37
Other services	13,913	85	2,409	15
Total	264,881	70	113,109	30

SOURCE: Reference 41.

maintenance and metal manufacturing are the most numerous industries and generate the most waste in both SQG categories.

Management Practices for Small-Quantity Generator Waste

Table 3-8 illustrates that most SQG waste is managed off-site (83 percent) and mostly by recycling. Much of the off-site recycling involves lead-acid batteries. The rest of the SQG waste is managed on-site, with 8 percent going to RCRA-exempt disposal in public sewers. Some SQG waste is treated on-site and then managed off-site.

Waste management practices by VSQGs differ somewhat from those of other SQGs. Of those VSQGs that manage waste on-site, 23 percent recycle waste, compared to 39 percent of the other SQGs. Among those that ship waste off-site, 61 percent of the VSQGs and 78 percent of the SQGs send it to recycling facilities.

The Florida hazardous waste generators and sanitary landfills study[46] presents summary statistics that include quantities and percentages of SQG hazardous wastes disposed of by various means. An extensive data base on characteristics of SQGs and MSWLFs in Florida was developed for this study. The numbers cannot be directly compared to the SQG survey data, however, since the disposal categories are set up differently.

The three previously mentioned, small-scaled surveys on small-quantity hazardous waste generators[42,43,44] identified some mismanagement of hazardous wastes. These surveys indicate that the need to educate small businesses about procedures for identifying, quantifying, managing, and handling hazardous wastes exists.

Other information relative to SQG hazardous waste management is available from the Subtitle D census and the Industrial Facilities Survey. The census solicited estimates of the numbers of Subtitle D landfills that receive SQG waste. As shown in Table 3-9, the respondents estimated that approximately one-third (31 percent) of the Subtitle D landfills receive SQG waste, and over half (53 percent) of municipal waste landfills receive SQG waste. The census estimated that 10 percent of LAUs and 15 percent of SIs receive SQG wastes. The Industrial Facilities Survey suggested that very few industrial establishments dispose of SQG waste in their on-site facilities. For example, less than 4 percent of the establishments with surface impoundments disposed of SQG waste in their impoundments.

Table 3-8. DISTRIBUTION OF OFF-SITE AND ON-SITE MANAGEMENT PRACTICES FOR SMALL-QUANTITY-GENERATOR WASTES

Management Practices	Approximate Amount of Waste (tons/year)[a]	Percent of Waste[b]	Percent of Generators[c]
Off-Site:			
Recycling	416,000	63	52
Solid waste facility	32,000	5	14
Subtitle C facility	25,000	4	4
Unknown	70,000	11	13
Total off-site	543,000	83	83
On-Site:			
Public sewer	51,000	8	14
Recycling	39,000	6	8
Treatment	25,000	4	6
Total on-site	115,000	18	28
Total off-site and on-site	658,000	101	111

SOURCE: Reference 39.

[a] Estimates based on Small Quantity Generator Survey data: 378,000 small-quantity generators provide detailed information for targeted wastes--approximately 658,000 tons/year of waste.

[b] Percentages are rounded and do not total 100 percent.

[c] Percentages do not add to 100 due to multiple management practices.

Table 3-9. ESTIMATED NUMBER OF LAND DISPOSAL FACILITIES RECEIVING SMALL-QUANTITY GENERATOR WASTE

Facility Type	Reported Number of Facilities	Response Rate (percent)	Reported Number of Facilities Receiving SQG Waste	Estimated Percentage of Facilities Receiving SQG Waste
Landfills:				
Municipal	9,284	88	4,327	52.9
Industrial	3,511	83	360	12.3
Demolition Debris	2,591	89	312	13.5
Other	1,030	28	76	26.7
Subtotal	16,416	84	5,075	37.1
Land Application Units:				
Municipal sewage sludge high rate	242	--	33	16.4
Municipal sewage sludge low rate	9,779	--	1,050	11.2
Municipal sewage total[a]	11,937	92	1,382	12.6
Industrial waste	5,605	95	164	3.1
Oil or gas waste	726	57	101	13.9
Other	621	100	0	0
Subtotal	18,889	90	1,647	9.6
Surface Impoundments:				
Municipal sewage sludge	1,938	75	548	37.6
Municipal run-off	488	77	157	41.5
Industrial waste	16,232	65	1,541	14.7
Agricultural waste	17,159	79	88	0.7
Mining waste	19,813	59	824	7.0
Oil or gas waste	125,074	77	17,746	18.5
Other	11,118	99	5	0.1
Subtotal	191,822	75	20,909	14.5

SOURCE: Reference 47.

[a] High-rate application and low-rate application may not equal the total municipal sewage sludge figures because some States do not distinguish between high-rate and low-rate LAUs when reporting the total, while others do make the distinction.

3.9 CONSTRUCTION AND DEMOLITION WASTE

Characteristics of Construction and Demolition Waste

Solid waste from construction and demolition of structures includes mixed lumber, roofing and sheeting scraps, broken concrete, asphalt, brick, stone, plaster, wallboard, glass, piping, and other building materials. The exact nature of construction and demolition waste depends upon the type of structures involved, and varies with geographical location and the age and size of a community.

Quantities of Construction and Demolition Waste

The quantities of demolition and construction waste reported in various locations across the nation range from 0.12 to 3.52 pounds per capita per day (pcd).[48] An urban average of 0.72 pcd was reported from 1970 data.[49] A California study reported 0.27 pcd for communities with fewer than 10,000 people, 0.68 pcd for communities of between 10,000 and 100,000 people, and 1.37 pcd in communities of over 100,000 people.[50] A study of waste generation in the Kansas City area estimated quantities of demolition and construction wastes at about 0.6 pcd.[51] At an average of 0.72 pcd,[49] the total quantity of construction and demolition waste generated in the United States is estimated at approximately 31.5 million tons per year. This is about 22 percent as much as the municipal solid waste disposed of in 1986.[1,2]

Management Practices for Construction and Demolition Waste

Management options for construction and demolition waste include recycling, reclaiming, or direct disposal in municipal, industrial, and demolition debris landfills and waste piles. However, the fraction of construction and demolition waste received at any of these facilities is unknown. Since most of this waste is generally viewed as requiring less stringent disposal than MSW, special demolition debris landfills are often used.[1]

3.10 AGRICULTURAL WASTE

Agricultural waste includes animal wastes from feedlots and farms, crop production wastes, irrigation wastes, and collected field run-off. Irrigation return flows and agricultural wastes, such as manures and crop residues that are returned to the soil as fertilizers or soil conditioners, are exempt from regulation under RCRA.

A total of 2.0 billion tons of wet manure are produced each year from livestock on American farms.[52] The portion of this waste regulated by RCRA (i.e., that is not returned to the soil) is not known. Other constituents found in these wastes, especially from feedlots and barnyards, are nutrients, organic matter, ammonia, fecal bacteria, and other microorganisms. Crop production wastes, irrigation wastes, and collected field run-off have not been well characterized. The total volume of these wastes produced annually is unknown.

Information on agricultural SIs has been collected in The Surface Impoundment Assessment National Report.[53] The objective of this study was to identify all existing SIs. The study counted agricultural SIs and categorized them by the type of agricultural production facility. A total of 19,437 agricultural SIs were identified by this survey, 270 of which were classified as abandoned SIs. Because the study relied on secondary sources of data such as United States Geological Survey maps, permit files, and well drillers' reports, the number of agricultural SIs reported may be low. Actual volumes of waste placed in the agricultural SIs were not reported. The number of SIs located, broken down by facility type, is presented in Table 3-10.

Table 3-10. DISTRIBUTION OF SURFACE IMPOUNDMENTS BY AGRICULTURAL PRODUCTION FACILITY

Agricultural Production Facility	Number of SIs Located[a]
Dairy farms	4,732
Hogs	3,492
Cattle feedlot	2,974
General farms	1,208
Poultry farms	717
Other fur-bearing animals	336
Crop production	190
Fish hatcheries	95

SOURCE: Reference 53.

[a] The States of Louisiana and Nevada are not included in this inventory.

The Subtitle D census reported a total of 17,159 active agricultural SIs. Fewer States provided estimates of numbers of SIs for the Subtitle D census as compared to the national SI Assessment. The Subtitle D census also reported that 93 percent of all agricultural SIs receive 50,000 or fewer gallons of agricultural waste per day. Assuming that the average agricultural SI receives less than 50,000 gallons per day, EPA estimates that 1 billion gallons per day is an upper limit to the amount of agricultural waste disposed of in SIs.

3.11 OIL AND GAS WASTE

Congress temporarily exempted from regulation under RCRA Subtitle C, pending further study by EPA, drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of crude oil or natural gas. These wastes are the subject of another report to Congress prepared by EPA which was issued in December 1987.[54] The oil and gas wastes are characterized by high concentrations of chloride, total dissolved solids, barium, sodium, and calcium. Preliminary data from the oil and gas report to Congress indicate that the quantity of produced waters generated annually falls between 11.7 and 16.3 billion barrels, and the range for drilling waste is 0.46 to 2.44 billion barrels. The Subtitle D Census identified 125,074 oil and gas SIs.

3.12 UTILITY WASTE

Congress also exempted wastes generated from the combustion of fossil fuels from regulation under Subtitle C of RCRA pending further study by EPA. Approximately 90 percent of the wastes generated from the combustion of fossil fuels comes from coal-fired electric power plants. These coal-combustion wastes are the subject of another EPA report to Congress[55] which was issued in February 1988.

Data from the report to Congress indicate that in 1984 coal-fired electric power plants generated 69 million tons of ash and 16 million tons of flue gas desulfurization (FGD) wastes. There are also several different types of low-volume wastes generated in the routine cleaning of plant equipment and in purifying water used in the combustion process. Examples of these low-volume wastes include boiler blowdown, metal and boiler cleaning wastes, and coal pile run-off.

Approximately one-fifth of the large-volume wastes are recycled. The rest of the waste is disposed of in SIs and landfills. Results of the report to Congress indicate that coal combustion waste streams generally do not exhibit hazardous characteristics as defined in the current Federal hazardous waste regulations under Subtitle C of RCRA.

3.13 MINING WASTE

Mining waste included as RCRA solid waste is the product of activities such as extraction, beneficiation (e.g., crushing, screening, washing, and flotation), smelting, and refining. High concentrations of heavy metals, sulfate, sodium, and potassium can be present.

In December 1985, EPA issued a first report to Congress[56] on mining wastes (other than coal mining wastes) and is continuing to gather data to support rulemaking efforts. The first report indicated that 1.4 billion tons of mining waste (other than coal mining waste) are produced each year from the extraction and beneficiation of metals, phosphate, asbestos, and oil shale. A second report is currently being prepared by EPA covering the extraction and beneficiation of aluminum, bauxite, copper, lead, zinc, and zinc oxide. The EPA is planning a third report to Congress on those mining wastes not covered in the first two reports.

The National SI Assessment counted mining SIs and categorized them by the material mined but did not report the rates of waste input. The numbers of SIs are listed in Table 3-11 to give a qualitative measure of the characteristics of mining waste.

Table 3-11. NUMBER OF MINING SURFACE IMPOUNDMENTS BY THE MATERIAL MINED

Material Mined	Number of SIs
Bituminous coal and lignite	19,891
Nonmetals	2,272
Metals	1,754
Anthracite	459
Total	24,376

SOURCE: Reference 53.

3.14 SUMMARY

Chapter 3 provides information on the characteristics, quantities, and management methods of Subtitle D wastes. This information was compiled to assess the hazards posed by releases of Subtitle D wastes to the environment. The following categories of Subtitle D wastes were identified for this report: MSW, MWC ash, HHW, municipal sludge, waste tires, industrial nonhazardous waste, SQG waste, construction and demolition waste, oil and gas waste, utility waste, agricultural waste, infectious waste, and mining waste.

One hundred and fifty-eight million tons of MSW were produced in 1986. Eighty-three percent of this waste was disposed of in landfills, 10.7 percent was recycled, and 6.0 percent was used for energy recovery. The portion of MSW recovered for energy is projected to increase to 20 percent by the year 2000.[1,4]

Ninety percent of the ash produced from the combustion of MSW is disposed of in monofills and landfills. Dioxins, difuran, lead, and chromium are several constituents of concern in MWC ash. A comprehensive municipal waste combustion ash characterization study has been conducted under a separate effort.[25]

Motor oil, paint, household maintenance items, batteries, and miscellaneous electrical items comprise 58 to 69 percent of household hazardous waste.[13] These items are known to contain hazardous wastes such as toluene, xylene, methylene chloride, trichloroethylene, benzene, lead, mercuric oxide, and sulfuric acid.[14] Most HHW is mixed with municipal solid waste and ultimately disposed of in landfills. The fraction of HHW in the MSW stream will vary according to the season, household, and area of the country. Current data indicate that the fraction of HHW in the MSW stream ranges from 0.1 percent to 0.4 percent.

Approximately 6.9 million dry tons of sewage sludge and 3.5 million tons of water treatment sludge are generated annually.[17,18] Municipal sludges are composed of organic and inorganic constituents.

Approximately 240 million automobile and truck tires are discarded annually in the United States and can present health, safety, and handling problems.[29] Most of these tires (168 million) are disposed of either in junkyards, where they can become a breeding ground for mosquitoes, or in landfills, from which they can resurface if not anchored.

Approximately 7.6 billion tons of industrial nonhazardous wastes are generated annually by 17 major industries, with nearly 95 percent of these wastes generated by 10 industries.[37] The characteristics of the waste vary with the industry.

Small-quantity generators of hazardous waste produce 1.04 million tons of hazardous waste annually, which is approximately 0.5 percent of the total amount of hazardous waste generated annually. Very-small-quantity generators produce about 0.2 million ton of hazardous waste annually, which is about one-fifth of all SQG hazardous waste. Used lead-acid batteries represent the largest waste category and the largest number of generators.

The quantity of construction and demolition waste generated is approximately 31.5 million tons per year[49] and is comprised of a variety of building materials. Disposal options for construction and demolition waste include landfills and waste piles. The exact nature of construction and demolition waste depends upon the types of structures involved and varies with geographical location, and the age and size of a community.

The annual production rate of oil and gas drilling muds was approximately 102.7 billion gallons in 1985.[54] Oil and gas brines and drilling muds may contain high concentrations of chloride, total dissolved solids, barium, sodium, and calcium. A separate report to Congress has been prepared by EPA on oil and gas wastes.

Approximately 69 million tons of ash from coal-fired electric power plants was generated in 1984. In addition, these plants produced 16 million tons of FGD wastes. EPA has prepared a report to Congress[55] on these utility wastes.

Annual production rates of agricultural and infectious waste are not known. Agricultural waste may contain nutrients, organic matter, ammonia, fecal bacteria, and possibly pesticide residues. Infectious waste may be biologically hazardous or capable of producing an infectious disease.[26]

Mining waste is produced at a rate of 1.4 billion tons per year, 99 percent of which is nonhazardous.[56] Heavy metals, acids, asbestos, and radionuclides can be present in mining waste.

3.15 REFERENCES

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Chapter 4

CHARACTERIZATION OF SUBTITLE D FACILITIES

According to the Subtitle D census, there are 227,000 Subtitle D units in the United States, 85 percent of which are surface impoundments (SIs). Land application units and landfills make up the remaining 8 percent and 7 percent of the universe, respectively. The census did not address waste piles. There are also 120,000 establishments that contain one or more Subtitle D units. Table 4-1 and Figure 4-1 describe this universe of Subtitle D facilities. The census indicated that in 1984 there were 33,000 establishments with only closed or inactive Subtitle D units.

This chapter presents statistics on the numbers and characteristics of Subtitle D facilities. The principal source of this information is the Census of State and Territorial Subtitle D Non-Hazardous Waste Programs.[1] Two other major data sources are the Industrial Subtitle D Facility Survey[2] and the Municipal Solid Waste Landfill Survey.[3] These two surveys were undertaken in order to fill data gaps in the Subtitle D census results for municipal solid waste landfills (MSWLFs) and industrial landfills, SIs, land application units, and waste piles.

Table 4-1. UNIVERSE OF SUBTITLE D FACILITIES

Facility Type	Number of Units	Number of Establishments
Landfills	16,416	15,719
Surface impoundments	191,822	108,383
Land application units	18,889	12,312
Waste piles	No Data[c]	No Data[c]
Total	227,127[a]	128,128[b]

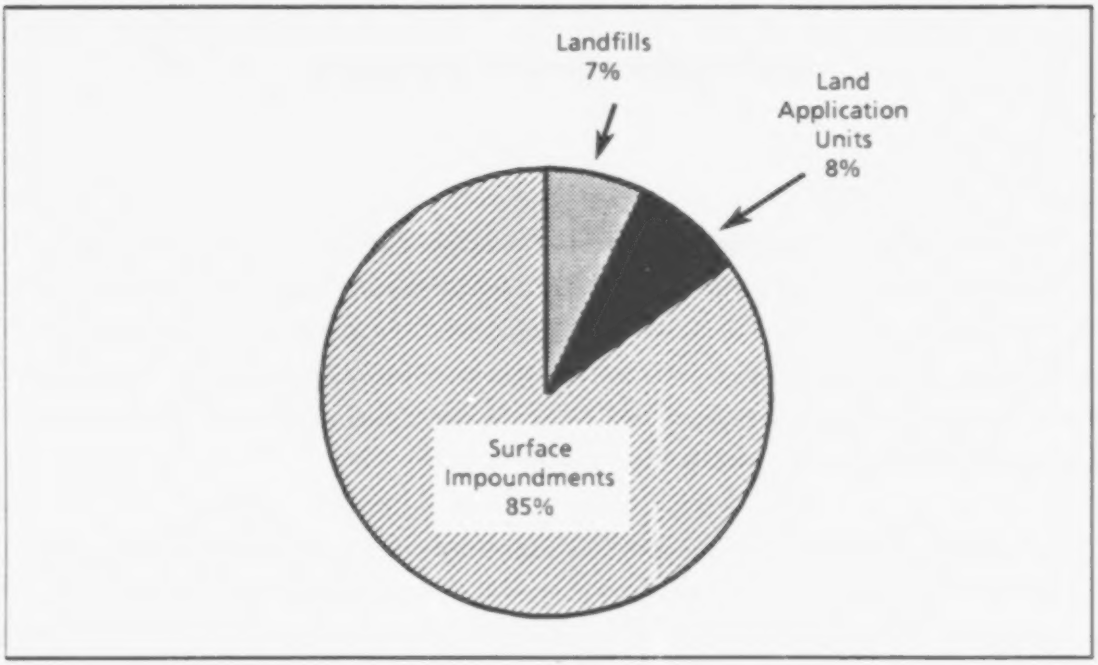
SOURCE: Reference 1.

[a] Sixteen percent (or approximately 36,000 units) are estimated to receive hazardous wastes from households or small-quantity generators.

[b] This is the correct total. The numbers for each type of facility do not add to this total, since two or more facility types or two or more of the same unit may exist at an establishment.

[c] The census did not address waste piles. Information on Industrial Waste Piles was provided by the Industrial Subtitle D Facility Survey and is presented later in this Chapter.

Figure 4-1. UNIVERSE OF SUBTITLE D UNITS, BY PERCENT



SOURCE: Reference 1.

4.1 LANDFILLS

This section first presents a profile of Subtitle D landfills. It then looks at the characteristics of the by-products of landfills--namely, leachate and gas; landfill design and operation; and the environmental and human health impacts of landfills.

4.1.1 GENERAL PROFILE

The Subtitle D census defined landfill as:

> A part of an establishment at which waste is placed in or on land and which is not a land application unit, a surface impoundment, an injection well, or a compost pile.

The census subdivided landfills into the following classes:

Municipal solid waste landfills primarily receive household refuse and nonhazardous commercial waste. They may also receive a limited amount of other types of Subtitle D waste, such as municipal sewage sludge and industrial wastes.

Industrial waste landfills receive nonhazardous waste from factories, processing plants, and other manufacturing activities. These landfills may also receive hazardous wastes from very-small-quantity generators (less than 100 kg/month).

Demolition debris landfills receive only construction or demolition debris.

Other landfills receive Subtitle D waste and do not fall into any of the above categories (for example, they receive only municipal sewage sludge).

In general, the data quality for MSWLFs was rated as good by the respondents of the census. Industrial waste estimates are thought to be underestimated to an unknown degree because some States do not have permitting requirements for on-site industrial waste landfills. The data on demolition debris landfills are also uncertain, but are probably more reliable than data for industrial landfills. The following subsections present data on the numbers, ownership, acreage, waste volumes, and capacity status of landfills.

Number of Landfills

Census results indicate that in 1984 there were 16,416 active Subtitle D landfill units located at 15,719 establishments across the United States. More than half of the landfills identified were MSWLFs. For this study, an establishment with one or more landfill units is considered as having one landfill unless otherwise specified (i.e., the word "units" appears in the discussion or in a table). Table 4-2 portrays the number and relative share of the total for each of the four types of landfills as determined by the State census and the MSWLF Survey. The survey estimated that there are approximately 6,000 MSWLFs in the United States.

The survey estimate of 6,000 MSWLFs differs from the 9,300 MSWLFs counted in the Subtitle D census. This discrepancy may be primarily attributed to inaccurate estimates by the States in the census, in part due to the different definitions of landfills used by the States. To a lesser extent, the census represents data collected in 1984, as compared with the MSWLF Survey, which includes 1986

Table 4-2. NUMBER OF SUBTITLE D LANDFILLS BY TYPE OF FACILITY

Landfill Type	Number of Landfills	Percentage of Landfills
Municipal Solid Waste	9,284 6,584[a]	57
Industrial Waste	3,511[b]	21
Demolition Debris	2,591[c]	16
Other	1,030	6
All Landfill Types	16,416	100

SOURCE: Reference 1, unless otherwise noted.

[a] Estimated number of landfill units from the Municipal Solid Waste Landfill Survey (Reference 3)

[b] No estimate of industrial waste landfills was obtained for Massachusetts or Michigan.

[c] No estimate of demolition debris landfills was obtained for Ohio.

data; thus the census may include a number of closed landfills. Although 6,000 is likely a more accurate estimate, 9,300 will be used in this report for consistency with other results from the census.

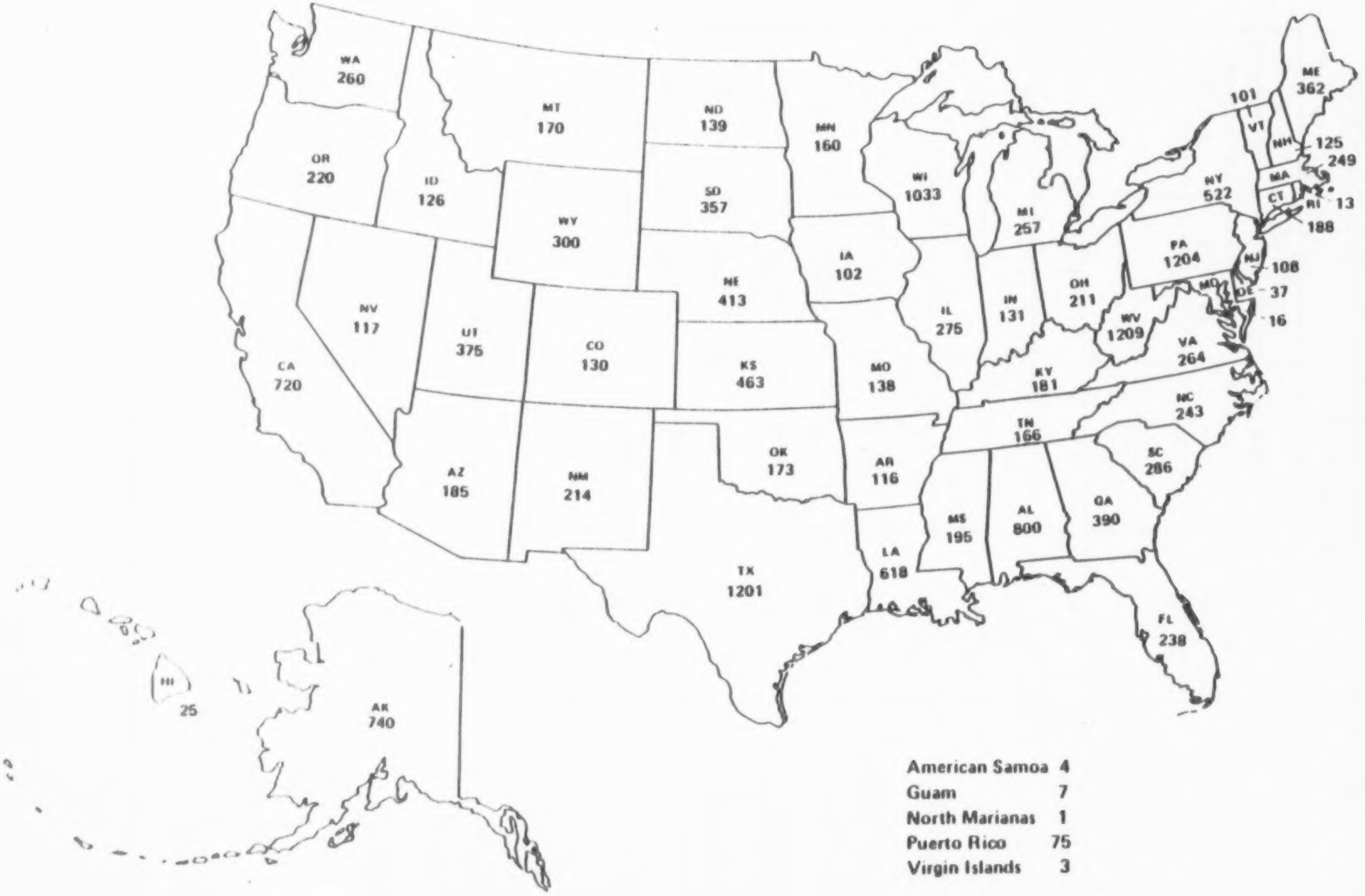
The distribution of landfills among States and territories determined from the census data is shown in Figure 4-2. West Virginia reported the largest number of Subtitle D landfills (1,209), followed by Pennsylvania (1,204), Texas (1,201), Wisconsin (1;033), Alabama (800), Alaska (740), and California (720).[1]

Table 4-3 presents results from the Industrial Facilities Survey of the numbers of Subtitle D industrial landfills for seventeen major industries. These results indicate that there are 2,757 active industrial landfills. The stone, clay, glass, and concrete industry accounts for nearly half of all the landfills.

Ownership of Landfills

Ownership data were reported for 15,578 (95 percent) of the Subtitle D landfills identified in the census. Just over half of these landfills are owned by local governments. A similar distribution of

Figure 4-2. NUMBER OF SUBTITLE D LANDFILLS BY STATE



American Samoa	4
Guam	7
North Marianas	1
Puerto Rico	75
Virgin Islands	3

SOURCE: Reference 1.

Table 4-3. NUMBER OF INDUSTRIAL ESTABLISHMENTS WITH LANDFILLS AND NUMBER OF LANDFILL UNITS

Industry Type	Total Number of Active Subtitle D Units[b]	Number of Active Landfill Units	Number of Establishments with Active Landfills	Number of Establishments with Closed Landfills
Organic Chemicals	385	17	13	39
Primary Iron and Steel	1,124	201	177	104
Fertilizer and Agricultural Chemicals	515	31	30	45
Electric Power Generation	1,528	155	126	89
Plastics and Resins Manufacturing	373	32	28	46
Inorganic Chemicals	1,281	120	81	115
Stone, Clay, Glass, and Concrete	7,247	1,257	1,153	454
Pulp and Paper	1,548	259	180	179
Primary Nonferrous Metals	880	111	90	93
Food and Kindred Products	8,029	194	189	140
Water Treatment	974	121	69	29
Petroleum Refining	1,249	61	41	66
Rubber and Miscellaneous Products	392	77	36	93
Transportation Equipment	723	63	56	127
Selected Chemicals and Allied Products	298	21	19	33
Textile Manufacturing	944	28	25	84
Leather and Leather Products	164	9	9	23
Total[a]	27,654	2,757	2,321	1,757

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

[b] These numbers correspond to the total universe of active Subtitle D units and include landfills, surface impoundments, land application units, and waste piles.

ownership of MSWLFs was determined by the MSWLF Survey. Table 4-4 presents the census and survey results.

Federally owned or operated Subtitle D facilities have recently become the subject of Congressional interest. Federal agencies that carry out solid waste disposal activities or allow other entities to engage in such activities on their land are responsible for ensuring compliance with the Federal criteria. (Federal agencies such as the Department of the Interior (DOI) often lease parcels of land to local governments or other entities for use as landfills.) In addition to the criteria found in 40 CFR Part 257, Federal facilities must also comply with requirements under Part 241 - Guidelines for the Land Disposal of Solid Wastes. These guidelines are recommended for non-Federal facilities.

The MSWLF Survey provided data on Federally-owned facilities. The survey results indicate that there are 193 MSWLFs that are Federally owned (this number does not include landfills located on Federal lands and operated by other entities). In general, the MSWLF Survey data indicate that these Federal facilities are operated and designed very much like the universe of MSWLFs. Federal facility data of interest are presented throughout this chapter.

Table 4-4. NUMBER OF LANDFILLS BY OWNERSHIP CATEGORY

Landfill Type	Survey Response Rate	Ownership Category[a]					Total[d]
		Owned by State Government	Owned by Local Government	Owned by Federal Government	Privately Owned	Other	
Municipal Solid Waste	96%	126 (1.4%)	6,908 (77.9%)	348 (3.9%)	1,482 (16.7%)	8 (0.1%)	8,872 (100%)
	97%[c]	49[c] (0.8%)	3,343[c,d] (57.1%)	193[c] (3.3%)	802[c] (13.7%)	1,465[c] (25%)	5,853[c] (100%)
Industrial Waste	97%	17 (0.5%)	74 (2.2%)	126 (3.7%)	3,177 (93.6%)	2 (0.1%)	3,396 (100%)
Demolition Debris Only	91%	33 (1.4%)	1,190 (50.5%)	82 (3.5%)	1,050 (44.6%)	0	2,355 (100%)
Other	93%	89 (9.3%)	203 (21.3%)	60 (6.3%)	603 (63.1%)	0	955 (100%)
All Landfill Types	95%	265 (1.7%)	8,375 (53.8%)	616 (4.0%)	6,312 (40.5%)	10 (0.1%)	15,578 (100%)

SOURCE: Reference 1, unless otherwise noted.

[a] Percentages are rounded and may not total 100 percent.
[b] Totals are for census data only unless otherwise specified.
[c] Landfill estimates from Municipal Solid Waste Landfill Survey (Reference 3). The survey identified a total of 6,034 landfills.
[d] City- and county-owned landfills only.

Acreage Covered by Landfills

Information on landfill acreage was supplied for 13,143 (80 percent) of the total Subtitle D landfills counted in the census. As shown in Table 4-5, more than half of all landfills were less than 10 acres, and about 95 percent were 100 acres or less. The Industrial Facilities Survey also provided acreage information. Nearly 75 percent of the establishments with landfills had landfills that were less than 10 acres. The results are presented in Table 4-6.

Table 4-5. NUMBER OF LANDFILLS BY ACREAGE CATEGORY

Landfill Type	Survey Response Rate	Acreage Category		
		Less than 10	10 to 100	More than 100
Municipal Solid Waste	75%	2,944 (42.3%)	3,572 (51.3%)	449 (6.4%)
Industrial Waste	88%	2,182 (70.7%)	834 (27.0%)	72 (2.3%)
Demolition Debris Only	84%	1,327 (60.6%)	797 (36.4%)	64 (2.9%)
Other	88%	831 (92.1%)	70 (7.8%)	1 (1.1%)
All Landfill Types	80%	7,284 (55.4%)	5,273 (40.1%)	586 (5.0%)

SOURCE: Reference 1.

Note: Percentages are rounded and may not total 100 percent.

Waste Volumes

Waste quantities were reported for 13,818 (84 percent) of the landfills identified in the census. Some quantities were reported in terms of volume (cubic yards per year), and others were reported in terms of weight (tons per day). Table 4-7 presents data on the amount of waste disposed of in the different types of landfills, as identified in the census. It indicates that most landfills (67 percent) receive less than 30 tons of waste per day, or 30,000 cubic yards of waste per year. The MSWLF Survey estimates that more than half (58 percent) of MSWLFs receive less than 10 thousand tons of waste annually, or approximately 38 tons daily if 260 operating days/year are assumed.

The Industrial Facilities Survey estimates that of the total waste quantity disposed of in industrial Subtitle D facilities, only 1.1 percent is disposed of in industrial landfills. The amount of waste disposed of in landfills for each of the 17 industries surveyed is presented in Table 4-8.

Table 4-6. NUMBER OF INDUSTRIAL ESTABLISHMENTS WITH LANDFILLS BY TOTAL AREA OF LANDFILLS IN EACH ESTABLISHMENT

Industry Type	Number of Establishments by Total Landfill Area (Acres)					Total Establishments Per Industry Type[a]
	Less than 5	5 - 10	11 - 50	51 - 100	More than 100	
Organic Chemicals	2	7	1	1	2	13
Primary Iron and Steel	49	61	45	15	6	176
Fertilizer and Agricultural Chem.	21	2	4	0	3	30
Electric Power Generation	17	18	30	29	31	126
Plastics and Resins Manufacturing	18	5	5	0	0	28
Inorganic Chemicals	29	17	28	5	2	81
Stone, Clay, Glass, and Concrete	788	177	132	9	16	1,122
Pulp and Paper	20	35	100	13	12	180
Primary Nonferrous Metals	54	9	21	4	1	90
Food and Kindred Products	120	6	58	5	0	189
Water Treatment	14	1	54	0	0	69
Petroleum Refining	20	12	8	0	1	41
Rubber and Misc. Products	11	1	13	10	1	36
Transportation Equipment	43	5	5	3	0	56
Selected Chem. & Allied Products	6	4	8	1	0	19
Textile Manufacturing	7	2	8	8	0	25
Leather and Leather Products	8	0	1	0	0	9
Total[a]	1,227	363	520	103	75	2,289[b]

SOURCE: Reference 2.

[a] The totals presented are the correct totals. The table entries have been rounded, and individual columns may not add to the specified total.

[b] Overall response rate for this table is 98.6 percent.

Table 4-7. NUMBER OF LANDFILLS BY AMOUNT OF WASTE RECEIVED IN 1984

Waste Type	Survey Response Rate	Quantity of Waste Received			Total Landfills Per Waste Type[a]
		<30,000 cu yds (<30 tons/day)	30,000-600,000 cu yds (30-500 tons/day)	>600,000 cu yds (>500 tons/day)	
Municipal Solid Waste	85%	5,309 (67%)	2,211 (28%)	408 (5%)	7,925 (100%)
Industrial Waste	82%	2,289 (79%)	523 (18%)	72 (2.5%)	2,884 (100%)
Demolition Waste	83%	1,608 (75%)	468 (22%)	78 (3.6%)	2,154 (100%)
Other Waste	85%	790 (93%)	51 (6%)	11 (1.3%)	852 (100%)

SOURCE: Reference 1.

[a] Percentages may not total 100 percent because of rounding.

Additional landfill waste quantity information from the Industrial Facilities Survey is presented in Table 4-9, which shows the distribution of the same industrial establishments according to the daily quantity of waste disposed of in their landfills during 1985. The survey results indicate that most (58 percent) of these landfills received less than 500 tons of waste in 1985.

Current Capacity of Landfills

Information related to capacity status is available for both municipal and industrial waste landfills. The census reported that in many States there are MSWLFs that are either reaching capacity, at capacity, or beyond capacity. A few States and territories reported that they had no landfill capacity problems. New sites for landfills were said to be difficult to obtain, highly opposed by the public, and costly. The shortage of landfill capacity has created a solid waste crisis in many States. Some States reported that incinerators and resource-recovery plants represent promising future alternatives to landfills, but were not viable alternatives for solving immediate capacity problems. Some States are considering recycling as an alternative. Appendix C contains specific State and territory responses to the census question on capacity status.

Data on the expected year in which MSWLFs will be filled were provided by the MSWLF Survey. Table 4-10 displays the estimated distribution of MSWLFs according to the date filled. The data indicate that more than one-third of all MSWLFs will close in 5 years. Data on the design capacity of MSWLFs were also provided from the MSWLF Survey and are presented in Table 4-11. The survey

Table 4-8. WASTE QUANTITIES DISPOSED OF IN INDUSTRIAL LANDFILLS IN 1985

Industry Type	Number of Establishments with Active Landfills	Waste Quantity Disposed of in Landfills (Thousand Tons)	Total Waste Quantity Disposed of in all Industrial Subtitle D Facilities (Thousand Tons)	Percent of Total Waste Disposed of in Landfills
Organic Chemicals	13	263	58,864	0.4
Primary Iron and Steel	177	3,687	1,300,541	0.3
Fertilizer & Agricultural Chemicals	30	5,789	165,623	3.5
Electric Power Generation	126	53,449	1,092,277	4.9
Plastics and Resins Manufacturing	28	86	180,510	0.05
Inorganic Chemicals	81	3,220	919,725	0.4
Stone, Clay, Glass, and Concrete	1,153	7,571	621,974	1.2
Pulp and Paper	180	5,873	2,251,700	0.3
Primary Nonferrous Metals	90	1,375	67,070	2.1
Food and Kindred Products	189	3,595	373,517	1.0
Water Treatment	69	157	52,846	0.3
Petroleum Refining	41	272	168,632	0.2
Rubber and Misc. Products	36	520	24,198	2.2
Transportation Equipment	56	172	12,669	1.4
Selected Chem. & Allied Products	19	112	62,987	0.2
Textile Manufacturing	25	69	253,780	0.03
Leather and Leather Products	9	9	3,234	0.3
Total[a]	2,321	86,219	7,616,149	1.1

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

Table 4-9. NUMBER OF INDUSTRIAL ESTABLISHMENTS WITH LANDFILLS BY ANNUAL WASTE QUANTITY DISPOSED OF IN THEM IN 1985

Industry Type	Number of Establishments by Annual Quantity of Waste Disposed of in Landfills in 1985 (thousand tons)						
	Less than 0.5	0.5-5	5.1-20	21-100	101-1,000	More than 1,000	Total Establishments Per Industry Type[a]
Organic Chemicals	2	4	4	2	1	0	13
Primary Iron and Steel	69	55	29	13	9	0	176
Fertilizer & Agricultural Chemicals	25	2	0	0	2	1	30
Electric Power Generation	23	13	6	23	57	3	126
Plastics and Resins Manufacturing	18	6	2	2	0	0	28
Inorganic Chemicals	30	31	10	9	0	1	81
Stone, Clay, Glass, & Concrete	873	129	85	46	10	0	1,143
Pulp and Paper	26	14	83	44	12	0	179
Primary Nonferrous Metals	32	35	7	13	2	0	90
Food and Kindred Products	127	22	17	12	11	0	189
Water Treatment	33	33	0	3	0	0	69
Petroleum Refining	21	9	8	1	1	0	40
Rubber and Misc. Products	2	22	2	10	0	0	36
Transportation Equipment	37	8	7	7	1	0	54
Selected Chem. and Allied Products	6	6	6	1	0	0	19
Textile Manufacturing	12	6	7	0	0	39	25
Leather and Leather Products	8	0	1	0	0	0	9
Total[a]	1,344	396	274	181	105	5	2,305[b]

SOURCE: Reference 2.

[a] These are the correct totals. Table entries may not add to their respective totals due to rounding.

[b] Overall response rate for this table is 99.3 percent.

Table 4-10. REMAINING LIFE OF MUNICIPAL SOLID WASTE LANDFILLS

Remaining Years (Closure year minus 1986)	Number of Landfills	Percentage of Landfills
0	535	8.9
1-5	2,167	35.9
6-10	612	10.1
11-15	1,126	18.7
16-20	360	6.0
More than 20	1,234	20.4
All Years	6,034	100

SOURCE: Reference 3.

Table 4-11. NUMBER OF MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS BY TOTAL DESIGN CAPACITY

Design Capacity (thousand tons)	Number of Landfill Establishments	Percentage of Landfills
Less Than 5,500	5,407	89.6
5,500 - 11,000	263	4.4
12,000 - 22,000	115	1.9
23,000 - 44,000	50	0.8
More than 44,000	32	0.5
Unknown	167	2.8

SOURCE: Reference 3.

estimates that most MSWLF establishments (approximately 90 percent) were designed to receive less than 5,500 thousand tons of waste.

Landfill capacity information from the Industrial Facilities Survey is presented in Tables 4-12 and 4-13. The survey data indicate a fairly even distribution of design capacity among on-site industrial landfills, as shown in Table 4-12. Table 4-13 indicates that approximately 95 percent of the total design capacity of industrial landfills used by the seventeen major industries surveyed remains.

Information on the ages of landfills was available for MSWLFs only. The MSWLF Survey indicates that very few MSWLFs have opened in the last 5 years and greater than half are more than 15 years old. The results are presented in Table 4-14. Data on the number of MSWLFs owned by the Federal government are presented in Table 4-15. In general, the breakdown of Federally-owned MSWLFs is proportional to that of the entire MSWLF population. The following approximate numbers of new landfill and landfill expansion approvals by the States were reported from another study:[4] 559 landfills and 139 expansions in 1981, 524 landfills and 151 expansions in 1982, and 416 landfills and 141 expansions in 1983. The number of expansion approvals has remained relatively constant over this period, but approvals for new landfills have dropped almost 25 percent over the same 3-year period. Considering that approximately one-third of the MSWLFs will close in 5 years, this decrease in the number of new landfills may increase the capacity problem in some areas.

Waste Characteristics

Municipal solid waste and industrial waste are the major categories of waste that can be found in Subtitle D landfills. Other waste types include agricultural waste, municipal sludge, construction and demolition debris, incineration ash, small-quantity generator (SQG) hazardous waste, infectious waste, and waste tires. Most of these wastes are in solid form, although municipal and industrial sludges are common. Chapter 3 presents available data on the physical and chemical characteristics of wastes in each of these categories.

Tables 4-16 and 4-17 present data from the MSWLF Survey on the types of waste in MSWLFs. Table 4-16 presents the mean composition of various waste types. Survey results indicate that most of the wastes in MSWLFs are generated by households and commercial establishments. Table 4-17

Table 4-12. NUMBER OF INDUSTRIAL ESTABLISHMENTS WITH LANDFILLS BY LANDFILL DESIGN CAPACITY PER ESTABLISHMENT

Industry Type	Number of Establishments by Design Capacity (thousand tons)						Total Establishments Per Industry Type[a]
	Less than 0.5	0.5-5	5.1-20	21-100	101-1,000	More than 1,000	
Organic Chemicals	1	0	2	5	4	1	13
Primary Iron and Steel	3	24	51	25	49	11	163
Fertilizer & Agricultural Chemicals	19	1	4	2	0	3	29
Electric Power Generation	6	5	5	12	21	74	124
Plastics and Resins Manufacturing	8	2	8	4	7	0	28
Inorganic Chemicals	1	12	20	18	20	3	74
Stone, Clay, Glass, and Concrete	177	234	176	127	162	71	947
Pulp and Paper	0	1	17	47	79	26	169
Primary Nonferrous Metals	9	13	26	8	20	3	79
Food & Kindred Products	91	33	4	18	39	1	186
Water Treatment	24	3	28	7	4	1	66
Petroleum Refining	2	5	8	9	6	1	32
Rubber and Misc. Products	0	0	0	2	11	11	25
Transportation Equipment	31	1	2	10	5	2	53
Selected Chemicals & Allied Products	0	1	4	5	4	1	15
Textile Manufacturing	1	2	0	5	2	0	10
Leather and Leather Products	0	3	3	0	1	0	7
Total[a]	373	342	358	304	433	209	2,020[b]

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

[b] Overall response rate to this table is 87 percent.

Table 4-13. DESIGN CAPACITY OF INDUSTRIAL LANDFILLS BY INDUSTRY TYPE

Industry Type	Number of Establishments with Active Landfills	Total Design Capacity (Thousand Tons)	Remaining Design Capacity (Thousand Tons)
Organic Chemicals	13	6,284	4,011
Primary Iron and Steel	177	61,056	42,870
Fertilizer & Agricultural Chem.	30	149,252	63,307
Electric Power Generation	126	999,469	874,358
Plastics and Resins Manufac.	28	2,200	1,514
Inorganic Chemicals	81	69,167	8,593
Stone, Clay, Glass, & Concrete	1,153	8,883,934	8,538,009
Pulp and Paper	180	108,457	229,337
Primary Nonferrous Metals	90	21,460	13,818
Food and Kindred Products	189	23,758	13,078
Water Treatment	69	3,374	1,782
Petroleum Refining	41	9,200	2,357
Rubber and Misc. Products	36	18,456	5,657
Transportation Equipment	56	7,335	2,003
Selected Chem. & Allied Prod.	19	3,056	3,285
Textile Manufacturing	25	697	728
Leather and Leather Prod.	9	178	120
Total[a]	2,321	10,367,356	9,804,831

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

Table 4-14. AGE OF MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS
(Number of Units)

Age of Facility (as of 1986)	Number of Landfills	Percentage of Landfill Establishments (% of units)
Less than 5	563 (1,715)	9.5 (26.0)
5 - 10	1,036 (1,229)	17.5 (18.7)
11 - 15	1,583 (1,300)	26.7 (19.7)
16 - 20	963 (820)	16.3 (12.5)
21-25	434 (333)	7.2 (5.0)
26-30	357 (309)	5.9 (4.7)
More than 30	988 (783)	16.4 (11.9)
Unknown	110 (95)	1.8 (1.4)

SOURCE: Reference 3.

Table 4-15. AGE OF FEDERALLY-OWNED MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS

Age of Facility (years as of 1986)	Number of Federally-Owned Landfills	Percentage of Federally-Owned Landfill Establishments
Less than 5	6	3.1
5 - 10	32	16.6
11 - 15	49	25.4
16 - 20	39	20.2
More than 20	67	34.7
Total	193	100

SOURCE: Reference 3.

presents data on the number of MSWLFs receiving selected types of industrial waste. The results indicate that all of the industries listed send some of their waste streams to MSWLFs.

Table 4-18 presents results from the MSWLF Survey on the percentage of liquids in the waste at MSWLFs. Survey results indicate that the great majority (more than 95 percent) of MSWLFs do not accept liquid wastes. The Industrial Facilities Survey indicates that very few of the industrial establishments surveyed receive off-site waste in their own on-site landfills. In addition, very few industrial SQGs (less than 100 kg/month) dispose of their hazardous waste in their own on-site Subtitle D landfills. These results are presented in Tables 4-19 and 4-20, respectively.

4.1.2 CHARACTERISTICS OF LEACHATE AND GAS FROM LANDFILLS

This subsection addresses the by-products of landfills -- namely, leachate and gas. The data presented are for MSWLFs only; information for other types of landfills was unavailable.

Leachate

Leachate composition and volume generation depend on many variables, including those inherent in the refuse mass and landfill location and those created by engineers and site operators. The availability of water, surface conditions, underlying soil conditions, landfill age or degree of stabilization, and refuse composition, condition, and depth all affect leachate composition and volume.[5]

Leachate data from 70 MSWLFs are presented in Tables 4-21 through 4-24. Fifty-three of these sites were analyzed for organic constituents and 62 of these sites were analyzed for inorganic constituents and selected parameters. The data have several limitations. Unknown variables include sampling and handling procedures, analytical methods, the list of constituents for which samples

Table 4-16. WASTE COMPOSITION OF MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS

Waste Type	Waste Composition Percentage (Mean Value)
Household Waste	71.98
Commercial Waste	17.19
SQG Hazardous Waste	0.08
Asbestos-Containing Waste	0.16
Construction/Demolition Waste	5.83
Industrial Process Waste	2.73
Infectious Waste	0.05
Municipal Incinerator Ash	0.08
Other Incinerator Ash	0.22
Sewage Sludge	0.50
Other Waste	1.18

SOURCE: Reference 3.

Table 4-17. MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS ACCEPTING INDUSTRIAL WASTE

Industrial Waste Type	Number of Landfills Receiving This Waste Type
Electric Power Generation	748
Fertilizer/Agricultural Chemicals	740
Food and Related Products and By-products	722
Inorganic Chemicals	750
Iron and Steel Manufacturing	719
Leather and Leather Products	732
Nonferrous Metals Manufacturing/Foundries	725
Organic Chemicals	750
Petroleum Refining Industry	740
Plastics and Resins Manufacturing	727
Pulp and Paper Industry	738
Rubber and Misc. Plastic Products	714
Stone, Glass, Clay, and Concrete Products	714
Textile Manufacturing	743
Transportation Equipment	733
Water Treatment	738
Other	746

SOURCE: Reference 3.

Table 4-18. NUMBER OF MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS BY PERCENTAGE OF LIQUIDS IN WASTE

Percentage of Liquids in Waste	Number of Landfills by Liquid Category		
	Bulk Liquids	Drummed/ Containerized Liquids	Drummed/Containerized Other Waste Forms
0.1 - 0.5	58	41	52
0.6 - 1	50	104	106
1.1 - 2	55	26	20
2.1 - 5	81	2	21
5.1 - 10	7	7	13
10.1 - 20	13	No data	8
20.1 - 40	No data	No data	No data
40.1 - 50	2	2	No data
50.1 - 100	20	No data	13

SOURCE: Reference 3.

Table 4-19. NUMBER OF INDUSTRIAL ESTABLISHMENTS WITH LANDFILLS RECEIVING OFF-SITE WASTE AND OFF-SITE HOUSEHOLD WASTE BY INDUSTRY TYPE

Industry Type	Number of Establishments with Active Landfills	Number of Establishments Accepting Off-Site Waste	Number of Establishments Accepting Off-Site Household Waste
Organic Chemicals	13	4	0
Primary Iron and Steel	177	25	21
Fertilizer & Agricultural Chem.	30	3	2
Electric Power Generation	126	10	2
Plastics and Resins Manufac.	28	1	0
Inorganic Chemicals	81	4	0
Stone, Clay, Glass, & Concrete	1,153	76	0
Pulp and Paper	180	19	1
Primary Nonferrous Metals	90	7	2
Food and Kindred Products	189	1	0
Water Treatment	69	7	2
Petroleum Refining	41	6	1
Rubber and Misc. Products	36	2	0
Transportation Equipment	56	0	0
Selected Chem. & Allied Prod.	19	1	0
Textile Manufacturing	25	1	1
Leather and Leather Products	9	0	0
Total[a,b]	2,321	168	32

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

[b] Overall response rate for this table is 91.4 percent.

Table 4-20. NUMBER OF SMALL-QUANTITY-GENERATOR INDUSTRIAL ESTABLISHMENTS THAT DISPOSE OF THEIR SMALL-QUANTITY-GENERATOR WASTE IN THEIR LANDFILLS BY INDUSTRY TYPE

Industry Type	Number of Establishments with Active Landfills	Number of SQG Establishments with Landfills	Number of SQG Estabs. Disposing of SQG Waste In Their Landfills
Organic Chemicals	13	0	0
Primary Iron and Steel	177	59	14
Fertilizer and Agricultural Chemicals	30	3	1
Electric Power Generation	126	73	1
Plastics and Resins Manufacturing	28	10	0
Inorganic Chemicals	81	16	0
Stone, Clay, Glass, and Concrete	1,153	373	26
Pulp and Paper	180	60	6
Primary Nonferrous Metals	90	38	10
Food and Kindred Products	189	61	1
Water Treatment	69	29	0
Petroleum Refining	41	5	0
Rubber and Miscellaneous Products	36	10	10
Transportation Equipment	56	5	0
Selected Chemicals and Allied Products	19	0	0
Textile Manufacturing	25	12	0
Leather and Leather Products	9	3	0
Total[a]	2,321	757	69

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

were analyzed, and landfill conditions. For some of the landfills, the age, location, design, refuse depth, and type of waste accepted are unknown. Finally, the data are from a relatively small number of facilities which may not be representative of all MSWLFs. Despite these limitations, the data presented may be used to formulate general observations.

Table 4-21 provides the current limited organic leachate data and Table 4-22 presents inorganic data as well as other leachate parameters. In general, these tables highlight the wide variability both in the constituents identified and their concentration ranges. Please note that every constituent was not analyzed for at every site. As mentioned above, the list of constituents for which samples were analyzed was unknown for several sites.

In order to provide some reference point for the risks associated with these leachate constituents, the leachate data were compared to EPA drinking water and/or human health criteria or EPA water quality criteria. These values are presented in Tables 4-21 and 4-22. In general, if an EPA drinking water standard (i.e., a maximum contaminant level - MCL) was available, that level was used. If an MCL was not available, an Agency-approved health-based level was used. For systemic toxicants, verified reference doses have been established and for carcinogens risk-specific doses have been developed. If a constituent is considered to act both as a carcinogen and a systemic toxicant, the lower value was used. Finally, if neither a standard nor a health-based level was available, EPA's water quality criteria were used. For some constituents, no values were available.

This analysis is very conservative because in all but the most extreme circumstances, MSWLF leachates will become diluted in ground water. However, in a number of cases the median concentrations would need to be diluted more than 1,000 times to reach the appropriate level. Therefore, there are some constituents that may be of potential concern.

Tables 4-23 and 4-24 present a breakdown of MSWLF organic and inorganic parameter constituents, respectively, according to the age at which the MSWLF began operation. The selection of pre- and post-1980 for comparison is thought to help distinguish between MSWLFs which accepted Subtitle C wastes from those which allegedly never accepted large-quantity-generator hazardous wastes. In addition, post-1980 MSWLFs began operation after the current Subtitle D criteria became effective. Only those constituents for which pre- and post-1980 data were available are presented. The available data do not indicate any trend. Median concentrations for post-1980 landfills are higher than those for pre-1980 landfills for approximately 50 percent of the constituents for which data were available for both.

Table 4-21. PRELIMINARY DATA ON CONCENTRATIONS OF ORGANIC CONSTITUENTS IN LEACHATE FROM MUNICIPAL SOLID WASTE LANDFILLS

Compound	Number of Sites at Which Constituent was Detected	Concentration Range (ppb)	Median Concentration (ppb)	Promulgated Standards or Criteria (ppb)
Acetone	12	8 - 11,000	430	4,000[a]
Acrolein	1	270 - 270	270	21[b]
Benzene	18	4 -1,080	37	5[c]
Bromomethane	1	170-170	170	10[a]
Butanol	1	1,000-1,000	1,000	
1-Butanol	2	320-360	340	
Butylbenzylphenol	2	21 - 150	125	
Carbon tetrachloride	2	6-398	202	5[c]
Chlorobenzene	8	1 - 685	7	1,000[a]
Chloroethane	7	11 - 860	28	
Bis-(2-Chloroethoxy) methane	2	18 - 25	22	
2-Chloroethylvinyl ether	1	2 - 1,100	551	
Chloroform	8	27-31	29	5.9[d]
Chloromethane	3	170 - 400	175	
Bis-(Chloromethyl) ether	1	250 - 250	250	0.0037[d]
2-Chloronaphthalene	1	46 - 46	46	
p-Cresol	5	45-5,100	2,305	2,000[a]
2,4-D	5	7 - 220	130	400[a]
4,4-DDT	5	0.042 - 0.22	0.105	0.1[d]
Dibromomethane	1	5-5	5	
1,2-Dichlorobenzene	5	3-22	12	3,000[a]
1,4-Dichlorobenzene	8	1 - 52	7	75[c]
Dichlorodifluoromethane	5	10-450	274	7,000[a]
1,1-Dichloroethane	20	4 - 44,000	165	0.58[d]
1,2-Dichloroethane	6	1 - 11,000	10	5[c]
Cis-1,2-Dichloroethylene	2	190-470	330	
Trans-1,2-Dichloroethylene	21	2-4,800	92	
1,2-Dichloropropane	9	0.03-500	9	5,700[b]
1,3-Dichloropropene	2	18 - 30	124	0.19[d]
Diethyl phthalate	12	3 - 330	83	460,000[a]
2,4-Dimethylphenol	2	10 - 28	19	2,120[b]
Dimethyl phthalate	2	30 - 55	43	313,000[b]
Di-n-Butyl phthalate	5	12 - 150	49	400[a]
Endrin	3	0.04-50	0.25	0.2[c]
Ethanol	1	2,300-2,300	2,300	
Ethyl acetate	2	42-130	86	

Table 4-21. (continued)

Compound	Number of Sites at Which Constituent was Detected	Concentration Range (ppb)	Median Concentration (ppb)	Promulgated Standards or Criteria (ppb)
Ethylbenzene	25	6 - 4,900	58.5	4,000[a]
Bis-(2-ethylhexyl) phthalate	8	16-750	80	70[a]
2-Hexanone	6	6 - 690	88	
Isophorone	6	4 - 16,000	76	5,200[b]
Lindane	1	0.017-0.023	0.020	4[c]
Methyl ethyl ketone	13	110-27,000	1,550	2,000[a]
Methyl isobutyl ketone	7	10 - 710	270	2,000[a]
Methylene chloride	32	2-220,000	440	4.8[d]
Naphthalene	13	2 - 202	12	620[b]
Nitrobenzene	3	4 - 120	40	20[a]
4-Nitrophenol	1	17 - 17	17	150[b]
Pentachlorophenol	2	3 - 470	45	1,000[a]
Phenol	21	7 - 28,800	378	1,000[a]
1-Propanol	1	11,000-11,000	11,000	
2-Propanol	4	94-26,000	8,450	
1,1,2,2-Tetrachloroethane	1	210 - 210	210	1.7[d*]
Tetrachloroethylene	11	2 - 620	55	6.7[d*]
Tetrahydrofuran	6	18-1,300	260	
Toluene	32	6-18,000	413	10,000[a]
Toxaphene	1	1-1	1	5[c]
1,1,1-Trichloroethane	13	1-13,000	86	200[c]
1,1,2-Trichloroethane	3	30 - 630	426	6.3[d*]
Trichloroethylene	17	1-1,300	43	5[c]
Trichlorofluoromethane	9	4-150	34	10,000[a]
1,2,3-Trichloropropane	1	230-230	230	7,000[a]
Vinyl chloride	6	8 - 61	40	2[c]
m-Xylene	7	10-171	68	
Xylenes	6	32 - 310	71	70,000[a]

SOURCE:

Reference 5	Reference 11	Reference 16
Reference 7	Reference 12	Reference 17
Reference 8	Reference 13	Reference 18
Reference 9	Reference 14	
Reference 10	Reference 15	

[a] Concentration based on U.S. EPA verified reference dose for systemic toxicants and the assumption of a 70-kg adult consuming 2 liters of water per day.

[b] EPA water quality criteria.

[c] Maximum contaminant level, EPA's drinking water standard.

[d] Constituent is considered a carcinogen by the oral route. Concentration is based on a unit risk of 10^{-6} except where noted.

[*] Concentration based on a 10^{-5} risk level (this is a class C carcinogen).

NOTE: The EPA is presently evaluating these data in a separate report titled Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics. This report is being prepared by NUS Corp. under contract 68-01-7310 as a background document for the work assignment "Criteria for Municipal Solid Waste Landfills."

Table 4-22. RANGE OF VARIOUS INORGANIC CONSTITUENT AND PARAMETER CONCENTRATIONS IN LEACHATE FROM MUNICIPAL SOLID WASTE LANDFILLS

Compound	Number of Sites at Which Constituent was Detected	Concentration Range (ppm)	Median Concentration (ppm)	Promulgated Standards or Criteria (ppm)
Alkalinity	29	470-57,850	2,650	
Aluminum	7	0.01 - 5.8	2.4	
Ammonia	44	0.39-1,200	209	
Antimony	9	0.0015-47	0.066	0.01[a]
Arsenic	36	0.0002-0.982	0.0135	0.05[b]
Barium	36	0.11 - 5	0.58	1.0[b]
Beryllium	6	0.001 - 0.01	0.005	0.2[a]
Biological Oxygen Demand	33	7-29,200	2,310	
Boron	8	0.63-12	4	
Cadmium	31	0.007-0.15	0.0135	0.01[b]
Calcium	19	96-2,100	320	
Chemical Oxygen Demand	52	42-50,450	2,800	
Chloride	52	31 - 5,475	594	
Chromium (Total)	43	0.0005-1.9	0.06	0.05[b]
Cobalt	2	0.04-0.13	0.08	
Conductivity (μmhos/cm)	55	300 - 36,000	5,600	
Copper	33	0.003-2.8	0.054	0.012[a]
Cyanide	13	0.004 - 0.02	0.03	0.7[a]
Eh (millivolts)	6	383-804	481	
Fluoride	18	0.11-302	0.39	
Hardness	26	0.8-9,380	1,665	
Iron	55	0.22-2,280	95	1,000[c]
Lead	45	0.005-1.6	0.063	0.05[b]
Magnesium	18	74 - 927	136	
Manganese	43	0.03 - 79	3.7	0.05[c]
Mercury	16	0.0001 - 0.01	0.0006	0.002[b]
Nickel	37	0.02 - 2.2	0.17	0.5[a]

Table 4-22. (continued)

Compound	Number of Sites at Which Constituent was Detected	Concentration Range (ppm)	Median Concentration (ppm)	Promulgated Standards or Criteria (ppm)
Nitrate	31	0.01 - 51	0.22	10[c]
Nitrite	8	0.005 - 0.2	0.03	
Nitrogen (Kjeldahl)	21	34-1,470	270	
Nitrogen (Organic)	9	4 - 100	50	
Nitrogen (Total)	1	505-505	505	
Phosphate	4	0.42-7	1.2	
Phosphorus	14	0.29-117	1.4	
Potassium	19	18-1,175	382	
Selenium	17	0.0008-0.05	0.02	0.01[b]
Silver	17	0.0008 - 0.035	0.012	0.05[b]
Sodium	37	12 - 2,574	693	
Sulfate	39	8-1,400	111	
Temperature (°C)	6	5-25	11	
Thallium	11	0.004 - 0.86	0.08	0.01[a]
Tin	3	0.16 - 2.0	0.23	
Total Dissolved Solids	28	390 - 31,800	4,890	20[c]
Total Organic Carbon (Nonpurgeable)	33	20-14,500	1,000	
Total Solids	8	1,900-33,050	10,658	
Total Suspended Solids	32	23 - 17,800	276	
Vanadium	6	0.009 - 0.029	0.08	
Zinc	50	0.03 - 350	0.68	0.110[c]
pH (standard units)	59	5.4 - 12.5	6.69	6.5-9[c]

SOURCE:
Reference 5
Reference 7
Reference 8
Reference 9
Reference 10
Reference 11
Reference 12
Reference 13
Reference 14
Reference 15
Reference 16
Reference 17
Reference 18
Reference 19

[a] Concentration based on U.S. EPA verified reference dose from systemic toxicants and the assumption of a 70-kg adult consuming a liter of water per day.

[b] Maximum contaminant level, EPA's drinking water standard.

[c] EPA's water quality criteria.

NOTE: The EPA is presently evaluating these data in a separate report titled Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics. This report is being prepared by NUS Corp. under contract 68-01-7310 as a background document for the work assignment "Criteria for Municipal Solid Waste Landfills."

Table 4-23. PRELIMINARY DATA ON CONCENTRATIONS OF ORGANIC CONSTITUENTS IN LEACHATE FROM MUNICIPAL SOLID WASTE LANDFILLS ACCORDING TO LANDFILL OPERATIONS START DATE

Compound	Data from Landfills that Started Operation Prior to 1980			Data from Landfills that Started Operation After 1980		
	Number of Sites at Which Constituent Was Detected	Concentration Range (ppb)	Median Concentration (ppb)	Number of Sites at Which Constituent Was Detected	Concentration Range (ppb)	Median Concentration (ppb)
Acetone	2	170-390	320	3	8-4,600	4,000
Chloromethane	1	170	170	1	400-400	400
p-Cresol	2	45-78	54	1	4,400-4,500	4,450
4,4-DDT	1	0.042	0.056	2	0.042-0.22	0.11
1,1-Dichloroethane	12	4-6,300	220	1	4-4	4
Trans-1,2-Dichloroethylene	13	7-3,130	168	2	6-677	14
Diethyl Phthalate	9	3-330	92	1	32-32	32
2-Hexanone	1	6-12	9	2	39-690	360
Isophorone	5	4-16,000	91	1	25-25	25
Methyl ethyl ketone	7	195 - 2,800	430	2	1,300-12,000	9,900
Methylene chloride	15	2-57,000	1,100	4	6-690	120
Phenol	12	7-15,800	258	2	378-2,100	1,700
Toluene	16	6-13,300	420	3	83-1,100	590

SOURCE:
Reference 5
Reference 7
Reference 8
Reference 9
Reference 10
Reference 11
Reference 12
Reference 13
Reference 14
Reference 15
Reference 16
Reference 17
Reference 18

NOTE: The EPA is presently evaluating these data in a separate report titled Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics. This report is being prepared by NUS Corp. under contract 68-01-7310 as a background document for the work assignment "Criteria for Municipal Solid Waste Landfills."

Table 4-24. RANGE OF VARIOUS INORGANIC CONSTITUENT AND PARAMETER CONCENTRATIONS IN LEACHATE FROM MUNICIPAL SOLID WASTE LANDFILLS ACCORDING TO LANDFILL OPERATIONS START DATE

Compound	Data from Landfills that Started Operation Prior to 1980			Data from Landfills that Started Operation After 1980		
	Number of Sites at Which Constituent Was Detected	Concentration Range (ppm)	Median Concentration (ppm)	Number of Sites at Which Constituent Was Detected	Concentration Range (ppm)	Median Concentration (ppm)
Alkalinity	17	960- 57,850	2,650	1	3,800 - 4,200	3,900
Aluminum	6	0.01- 6	3.3	1	2.2 - 3.4	2.6
Ammonia	21	1.6-1,100	215	4	0.39 - 810	299
Arsenic	24	0.0002- 0.982	0.015	4	0.003 - 0.04	0.011
Barium	22	0.11- 5	0.58	4	0.08 - 1.7	1.0
Biological Oxygen Demand	20	64-29,200	2,600	3	13 - 5,980	185
Cadmium	15	0.002-0.15	0.018	5	0.003 - 0.02	0.0065
Calcium	11	146-2,100	284	2	657 - 1,060	747
Chemical Oxygen Demand	29	266-50,450	2,817	5	42 - 16,000	4,300
Chloride	28	31-2,651	550	4	43 - 2,056	820
Chromium (Total)	28	0.002-1.9	0.06	6	0.006 - 0.37	0.08
Conductivity (µmhos/cm)	32	300-36,000	5,450	4	1,750 - 28,125	8,800
Copper	18	0.02-2.8	0.059	3	0.02 - 0.07	0.031
Eh (millivolts)	3	411-804	486	1	481 - 481	481
Fluoride	9	0.11-1.1	0.28	2	0.38 - 1.8	0.4
Hardness	17	670-9,380	1,550	1	2,800 - 3,000	2,900
Iron	31	2.1-2,280	93	4	2.6 - 695	230
Lead	24	0.031-1.6	0.072	5	0.007 - 0.15	0.046
Magnesium	10	74-780	138	2	275 - 424	412
Manganese	26	0.03-79	3.26	4	1 - 50	12
Nickel	21	0.02- 2.2	0.16	4	0.05 - 1.6	0.185

Table 4-24. (continued)

Compound	Data from Landfills that Started Operation Prior to 1980			Data from Landfills that Started Operation After 1980		
	Number of Sites at Which Constituent Was Detected	Concentration Range (ppm)	Median Concentration (ppm)	Number of Sites at Which Constituent Was Detected	Concentration (ppm)	Median Concentration (ppm)
Nitrate	19	0.01 - 1.4	0.135	3	0.04 - 0.66	0.22
Nitrite	3	0.005 - 0.112	0.01	1	0.05 - 0.05	0.05
Nitrogen (Kjeldahl)	15	34 - 1,470	235	2	81 - 390	380
Nitrogen (Organic)	3	4.5 - 100	50	1	40 - 60	45
Phosphorus	11	0.325-117	1.31	3	0.29 - 8	1.7
Potassium	14	18 - 1,175	239	1	363 - 472	462
Selenium	9	0.001 - 0.09	0.006	1	0.002 - 0.002	0.002
Silver	10	0.0008 - 0.035	0.012	2	0.026 - 0.037	0.036
Sodium	23	12 - 1830	596	4	69 - 2,574	817
Sulfate	23	8 - 1,400	118	3	24 - 1,300	260
Temperature (°C)	3	10 - 25	18	1	11 - 11	11
Total Dissolved Solids	14	390 - 16,120	4,230	3	7,020 - 31,800	7,976
Total Organic Carbon (Nonpurgeable)	17	74 - 13,000	810	4	20 - 14,500	2,860
Total Suspended Solids	22	23 - 17,800	264	4	32 - 960	554
Vanadium	3	0.009 - 0.024	0.014	1	0.016-0.024	0.0185
Zinc	25	0.03 - 350	0.88	4	0.06 - 6.4	0.335
pH (standard units)	33	5.4 - 12.5	6.58	6	6.17 - 8.39	6.91

SOURCE:
Reference 5
Reference 7
Reference 8
Reference 9
Reference 10
Reference 11
Reference 12
Reference 13
Reference 14
Reference 15
Reference 16
Reference 17
Reference 18

NOTE: The EPA is presently evaluating these data in a separate report titled Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics. This report is being prepared by NUS Corp. under contract 68-01-7310 as a background document for the work assignment "Criteria for Municipal Solid Waste Landfills."

Comparison of the pre- and post-1980 data has severe limitations. First, the previously discussed data limitations have more pronounced effects due to a smaller sample size. As mentioned above, for many of the landfills, the age was unknown. Consequently, for the pre- and post-1980 comparison, organic data were available for only 15 MSWLFs (10 pre- and 5 post-1980), and inorganic/ parameter data were available for only 20 MSWLFs (16 pre- and 4 post-1980). Second, examining the effect of the hazardous waste restriction is made difficult by the fact that some landfills may still be accepting hazardous waste illegally. Finally, leachate composition is affected by many variables, including time. Because leachate characteristics change over time, a comparison of the current post-1980 leachate data, which include leachates from landfills that are no more than 7 years old, with leachates from landfills that may be 40 years old may not reliably indicate changes in leachate composition. The Agency is currently initiating additional field sampling which will focus on post- 1980 landfills to supplement the data base.

Although relatively high densities of microorganisms have been found in MSW, a review of the literature[19] indicated that few microorganisms can survive in the leachate environment. Therefore, few microbes are transported away from the MSWLF after the solid waste has been in place a few months.

Two studies performed for the American Foundrymen's Society examined leachate characteristics at 14 ferrous foundry waste monofills.[20,21] The primary environmental impacts identified in the studies were the presence of cadmium, chromium, and lead in trace concentrations which were occasionally found in monofill leachate. Ground water at one facility was found to be contaminated with barium and mercury at concentrations exceeding the EPA primary drinking water standards. The EPA has not determined that the facilities examined in these studies are representative of ferrous foundry waste monofills in general.

Gas

Gas is produced in MSWLFs through bacterial decomposition of organic matter. The type of organics, rate of reaction, and completeness of the reaction are controlled by local site conditions, such as pH, temperature, moisture, and oxygen content (both gaseous and chemically available), which affect the bacterial population. Methane is produced within a landfill after the gas in the voids changes from aerobic to anaerobic and the chemically available oxygen in the refuse is consumed.

One of the potential benefits derived from landfill gas is that, because of its high methane content, it may be used as a fuel with applications similar to those of commercial natural gas. As the landfill gas is withdrawn from the landfill and cooled (naturally or artificially), landfill gas condensate is produced. In a recent limited study[22] conducted for EPA, condensate from four landfills was analyzed. The condensate is a two-phase liquid containing an aqueous phase and an organic phase. Condensate quality varied from site to site. Forty-nine priority pollutant compounds were identified in the condensate; 11 were detected in the organic phase at levels that exceed proposed regulatory limits.

Municipal solid waste landfill gas has been found to consist of about 50 percent methane and 40 to 50 percent carbon dioxide, plus 0.5 to 1 percent of hydrogen, oxygen, nitrogen, and other trace gases.[23] Table 4-25 presents data that support this statement. Typical trace components found in MSWLF gases are described in Table 4-26.[24] Only one compound (vinyl chloride) has a median concentration that exceeds Occupational Safety and Health Administration (OSHA) permissible exposure levels. Other compounds whose concentration range has exceeded these exposure levels in some samples are benzene, tetrachloroethylene, toluene, and xylene. No information was found for other landfill types. (The OSHA permissible exposure level is used for comparison only and represents the maximum safe level allowed in a workplace where long-term exposure exceeds eight hours per day or 40 hours per week.)

The volatile organic compounds (VOCs) discussed above are air contaminants not only because they represent human health risks, but also because they can lead to the formation of ozone, a priority air pollutant under the Clean Air Act. Total nationwide emissions of nonmethane organics are estimated to be in the range of 200,000 to 300,000 megagrams per year for active MSWLFs.

4.1.3 DESIGN AND OPERATION OF LANDFILLS

The following discussion of design and operating characteristics of Subtitle D landfills presents statistics under the topics of landfill design, landfill operation and maintenance, and environmental monitoring.

Table 4-25. TYPICAL COMPOSITION OF GAS FROM MUNICIPAL SOLID WASTE LANDFILLS

Component	Component Percentage (dry-volume basis)			
	Study 1	Study 2	Study 3	Study 4
Methane	44.0	47.5	50.0	53.4
Carbon dioxide	34.2	47.0	35.0	34.3
Nitrogen	20.8	3.7	13.0	6.2
Oxygen	1.0	0.8	1.7	0.05
Paraffin hydrocarbons	--	0.1	--	0.17
Aromatic and cyclic hydrocarbons	--	0.2	--	--
Hydrogen	--	0.1	0.3	0.005
Hydrogen sulfide	0.4-0.9	0.01	--	0.005
Carbon monoxide	--	0.1	--	0.005
Trace compounds[a]	--	0.5	--	--

SOURCE: Reference 23.

[a] Includes sulfur dioxide, toluene, methylene chloride, perchloroethylene, and carbonyl sulfide in concentrations ≤ 50 ppm.

Table 4-26. TYPICAL TRACE CONSTITUENTS IN MUNICIPAL SOLID WASTE LANDFILL GAS

Compound	Number of Sites Sampled	Number of Samples	Range of Concentration (Vppm)	Median Concentration (Vppm)	Standard Deviation (Vppm)	PEL[a] (Vppm)
Benzene	13	21	0 - 12	0.3	3.0	10
Ethylbenzene	11	14	0 - 91	1.5	24	100
Heptane	4	6	0 - 11	0.45	5.2	500
Hexane	8	9	0 - 31	0.8	11	500
Isopentane	5	7	0.05 - 4.5	2.0	1.5	--
Methylcyclohexane	6	7	0.017 - 19	3.6	8.8	500
Methylcyclopentane	6	7	0 - 12	2.8	4.4	--
Methylene chloride	10	17	0 - 118	0.83	30	500
Nonane	6	8	0 - 24	0.54	8.2	400
Tetrachloroethylene	13	19	0 - 186	0.03	44	100
Toluene	16	26	0 - 357	6.8	82	100
1,1,1-Trichloroethane	11	18	0 - 2.4	0.03	0.6	350
Trichloroethylene	12	19	0 - 44	0.12	10	100
Vinyl chloride	10	16	0 - 10	2.2	3.7	1
Xylene	5	6	0 - 111	0.1	48	100
m-Xylene	4	9	1.7 - 76	4.1	28	100
o-Xylene	7	9	0 - 19	1.8	7.7	100

SOURCE: Reference 24.

[a] PEL = Permissible exposure level prescribed by OSHA for workplace exposure. OSHA has proposed revising the PEL for benzene to 1 Vppm (Volume parts per million).

--- = No PEL set.

__ = Exceeds OSHA limit (PEL).

Landfill Design

This subsection outlines the major environmental protection elements in landfill design and presents available statistics on the frequency of their use. These elements are liners, leachate collection/removal systems, run-on/run-off controls, methane gas controls/recovery systems, cover and closure characteristics, and location factors.

Liners

The purpose of a liner is to limit migration of pollutants from the landfill into the ground water. A liner may be composed of soil or synthetic materials. Soil liners are typically compacted clays. Synthetic liners include a variety of low-permeability materials.

Soil Liners -- In-place soils are used to the maximum extent possible as liner material to save the costs of purchasing and hauling soils to the site. If appropriate clay soil does not exist, or exists only on a part of the site or at certain depths, imported clays or chemical additions are used. Many types of clays or mixes of clays (montmorillonite, kaolinite, illite, bentonite) are used, as well as artificial soil amendments. With proper quality control and construction techniques, clay liners can achieve permeabilities of approximately 10^{-7}centimeter per second.[25]

Synthetic Liners -- These types of liners are used when soil permeability is not adequate or economically attainable to prevent pollutant migration, or when required by regulations. These liners include asphalt and portland cement compositions, soil sealants, sprayed liquid rubbers, and synthetic polymeric (or flexible) membranes. Synthetic polymeric and asphaltic materials are the most common membrane liners used for landfills.[26] Using the best present construction and placement technologies, facilities can achieve permeabilities on the order of 10^{-10} centimeter per second.[25] Certain landfill waste and leachate can damage membrane liners. Damaging characteristics include high or low pH, oily waste, exchangeable ions, and organic compounds.

Tables 4-27, 4-28 and 4-29 present data on landfill liner status. Table 4-27 presents Subtitle D census data and shows that very few of the active landfills use any liners. Of those that do, most use natural liners. Municipal solid waste landfills tend to be the predominant landfill type to employ natural liners. Table 4-28 presents results from the MSWLF Survey on the distribution of MSWLF units using various liner technologies according to the age of the landfill. The data indicate that the use of synthetic liners has increased slightly in the last ten years. Table 4-29 presents results from the

Table 4-27. NUMBERS OF SUBTITLE D LANDFILL UNITS USING VARIOUS TYPES OF RELEASE PREVENTION METHODS

Management Method	Number of Units by Facility Type[a]					
	Municipal Solid Waste		Industrial Waste	Demolition Debris Only	Other	Total Units Per Management Method[c]
	Census	Municipal Survey[b]				
Synthetic Liners	71 (0.8%)	73 (1.1%)	45 (1.3%)	1 (<0.1%)	2 (0.2%)	119 (0.7%)
Natural Liners[d] (e.g., clay), including slurry walls	1,353 (14.6%)	1,806[d] (27.4%)	392 (11.2%)	117 (4.5%)	5 (0.5%)	1,867 (11.4%)
Leachate Collection Systems	481 (5%)	746 (11.3%)	112 (3.2%)	3 (0.1%)	6 (0.6%)	602 (3.7%)
Run-on/Run-off Controls	4,240 (45.7%)	4,016[b] (61.0%)	1,150 (32.8%)	685 (26.4%)	78 (7.6%)	6,153 (37.5%)
Methane Controls (vents, recovery)	1,539 (16.6%)	123[e] (1.9%)	98 (2.8%)	107 (4.1%)	3 (0.3%)	1,747 (10.6%)
Leachate Treatment[f] (except leachate recirculation)	245 (2.6%)	No Data	69 (2.0%)	1 (<0.1%)	2 (0.2%)	317 (1.9%)
Leachate Recirculation	205 (2.2%)	228[a] (3.5%)	27 (0.8%)	0	0	232 (1.4%)
Restrictions on Receipt of Liquid Wastes (e.g., bulk liquid restrictions)	4,436 (47.8%)	No Data	1,200 (34.2%)	818 (31.6%)	128 (12.4%)	6,582 (40.1%)

Source: Reference 1.

[a] Percentages are relative to approximately 9,300 (for census data) or 6,600 (for survey data).

[b] Estimate from Municipal Solid Waste Landfill Survey. (Reference 3)

[c] Total is for census estimates only.

[d] Only in-situ clay liners are identified for this entry. See table 4-28 for more detail on facilities natural liners as identified by the Municipal Solid Waste Landfill Survey.

[e] Survey results estimate only the number of recovery systems.

Table 4-28. NUMBER OF ACTIVE AND PLANNED MUNICIPAL SOLID WASTE LANDFILL UNITS BY TYPE OF LINER AND AGE OF DISPOSAL UNIT

Age of Unit (years as of 1986)	Number of Units by Liner Type					
	Natural Liners			Synthetic Liners (e.g., membrane, asphalt)	Other Liners	No Liners or Unknown
	Soil	Clay	Re-Compacted Clay			
Planned Units	523	1,015	673	201	271	1,163
Less than 5	372	597	473	42	122	429
5 - 10	151	412	230	13	141	425
11 - 15	289	328	256	10	59	495
16 - 20	174	161	102	13	28	409
Greater than 20	362	263	140	3	80	796
Unknown Age	15	45	13	3	8	26

SOURCE: Reference 3.

Table 4-29. NUMBER OF ACTIVE FEDERALLY-OWNED MUNICIPAL SOLID WASTE LANDFILL UNITS BY TYPE OF LINER AND AGE OF DISPOSAL UNIT

Age of Unit (years as of 1986)	Number of Federally-Owned Units by Liner Type					
	Natural Liners			Synthetic Liners (e.g., membrane, asphalt)	Other Liners	No Liners or Unknown
	Soil	Clay	Re-Compacted Clay			
Less than 5	19	26	13	0	0	21
5 - 10	26	19	0	0	13	19
11 - 15	2	15	6	0	6	13
16 - 20	0	6	0	0	0	13
Greater than 20	13	6	0	0	0	15

SOURCE: Reference 3.

MSWLF Survey on Federally-owned MSWLF units using various liner technologies according to the age of the landfill. Table 4-29 illustrates a slight increase in the use of liners over the past 20 years at Federally-owned MSWLFs.

Leachate Controls/Removal Systems

These systems refer to the control and collection, composition control, treatment, and recirculation systems of leachate.

Leachate Control and Collection -- Control and collection techniques have been well established. They include drains, wells, liners, slurry trenches, cut-off walls, grading (run on), and surface sealing. As noted in Table 4-27, the census indicated that 490 of all MSWLF units have leachate collection systems and the MSWLF Survey indicates that approximately 11 % have a collection system.

The MSWLF Survey provided information on the number of MSWLF units using various leachate collection technologies and management practices. Table 4-30 presents the number of MSWLF units using various leachate collection technologies and the total number that employ any system according to unit age. The survey indicates that sumps and drainage tile/pipe are the most predominantly used leachate collection technologies. Table 4-31 presents the number of closed, active, and planned landfill units using various leachate management practices. Recirculating by spraying and trucking to publicly owned treatment works (POTW) is the most common management method.

Leachate Composition Control -- Composition can be controlled through design and operating features and by addition of selected sorbents into the fill. Landfill design and operating features that are significant to leachate composition are the chemical and physical characteristics of waste placed in the landfills, including particle size (shredding) and density (compaction and baling); rate of water application; landfill depth or lift height; and landfill temperature (which can be regulated to some extent through cover material, refuse density, and lift height).[27]

Leachate Treatment Processes -- Leachate can be treated by existing wastewater plants, or by processes specifically designed for landfill leachate. Available technologies include aerobic/anaerobic biological processes, and physical/chemical processes. The census results presented in Table 4-27 indicate that approximately 2 percent of the Subtitle D landfills use leachate treatment other than leachate recirculation. Most of these are MSWLFs. The census and the MSWLF

Table 4-30. NUMBER OF ACTIVE MUNICIPAL SOLID WASTE LANDFILL UNITS BY TYPE OF LEACHATE COLLECTION SYSTEM AND AGE OF UNIT

Age of Unit (years as of 1986)	Sand Drainage Layer	Gravel Layer	Filter Fabric Layer	Plastic Drainage Net	Sumps	Drainage Tile/Pipe	Interceptor Trenches	Other Types	Number of Units with a Collection System[a]
Less than 5	82	64	21	7	102	198	115	29	306
5 - 10	18	19	11	2	49	60	58	32	134
11 - 15	26	11	7	0	28	68	75	23	146
16 - 20	15	8	8	0	16	24	34	3	55
More than 20	3	29	10	8	31	52	44	34	92
Unknown Age	10	2	3	0	13	11	10	0	13
Total	154	133	60	17	239	413	336	121	746

SOURCE: Reference 3.

[a] Please note, this is not a total column. Many units employ more than one system. This is the number of units that have any type of leachate collection system.

Table 4-31. NUMBER OF MUNICIPAL SOLID WASTE LANDFILL UNITS BY TYPE OF LEACHATE MANAGEMENT PRACTICE AND OPERATING STATUS

Type of Leachate Management Practice[a]	Number of Landfills		
	Closed	Active	Planned
Recirculate by Spraying	40	158	185
Recirculate by Injection	10	36	16
Recirculate by Other Means	11	34	22
Land Spreading	15	84	60
Truck to POTW	48	76	245
Discharge to Sewer to POTW	53	118	135
Discharge to Surface Water	28	81	26
Other or Unknown Off-Site Treatment	5	21	23
On-Site Biological Treatment	41	102	108
On-Site Chemical/Physical Treatment	34	61	60

SOURCE: Reference 3.

[a] Some facilities have more than one leachate management practice.

Survey indicate that approximately 3 and 10 percent, respectively, of the MSWLFs use treatment processes other than recirculation.

Leachate Recirculation Systems -- A full-scale leachate recycle study performed at the Lycoming County, Pennsylvania, MSWLF [28] concluded that leachate recycle systems result in more rapid decomposition of organic waste, and enhanced methane production, and increase the stabilization rate. Other factors found to affect decomposition rates and methane production were landfill age, type of soils employed as cover materials, moisture content of the waste, and climate.

While recirculation has certain benefits, there are drawbacks to using it as a treatment method. Reintroducing leachate into a landfill will result in an increased leachate production rate. The increased volume of leachate may clog the leachate collection system and present an increased threat to ground water. Subtitle D census results presented in Table 4-27 show that approximately 1.4 percent of all landfills use this treatment process, and MSWLFs comprise the largest user category. According to the census and the MSWLF Survey, approximately 3 percent of the MSWLFs used recirculation systems.

Run-on/Run-off Controls

Run-on/run-off controls are important to landfill pollution control, since run-on contributes to leachate generation and can cause harmful compounds to be swept out of the landfills. Subtitle D census results presented in Table 4-27 show that approximately 37 percent of all landfills employ these controls, and MSWLFs comprise the largest user category. The census estimated that roughly 46 percent of MSWLFs used run-on/run-off controls while the MSWLF Survey estimated that 61 percent used these controls. This discrepancy is most likely due to inaccurate reporting by the States.

Tables 4-32 and 4-33 present results from the MSWLF Survey on the number of MSWLFs using various run-on/run-off control technologies. Table 4-32 presents data on planned and active MSWLFs, and Table 4-33 presents data on closed MSWLFs. The results indicate that the use of diversion berms and ditches has increased over the past 15 years.

Methane Gas Controls/Recovery Systems

Many factors determine the feasibility of a methane gas recovery system at a landfill. Since the gas generation process depends on several environmental variables, it is difficult to predict the exact production rate, volume, and composition of the gas. Nevertheless, different kinds of collection systems have been designed, depending on whether the purpose of collection is migration control and/or recovery.

Table 4-27 presents census data on landfills using methane controls. About 11 percent of all landfills employ these controls, and most of these facilities are MSWLFs. This reflects the fact that MSWLFs generally produce significant quantities of methane (see discussion of leachate and gas characteristics), while other landfills generally do not. Table 4-34 presents the results from the MSWLF Survey on the distribution of MSWLFs using methane gas recovery systems according to the age of the landfill. The results indicate that only a small number (less than 2 percent) of MSWLFs are attempting to recover methane emissions. Most of the methane monitoring and recovery systems are in landfills that are more than 10 years old. This is because several years are necessary before solid waste begins to generate significant amounts of methane. The remaining discussion on landfill gas applies mainly to MSWLFs.

Collection -- A landfill gas-recovery system is designed to maximize gas recovery without disturbing the anaerobic conditions within the landfill. Recovery systems typically include extraction wells at the interior of the fill, a pump, and a collection pipe network. Gas migration control systems were originally designed to prevent buildup and migration beyond the landfill boundary using wells or trenches at the landfill's exterior to vent the gas. Current trends are to tie together the migration and recovery systems to increase gas collection.[23]

Table 4-32. NUMBER OF ACTIVE MUNICIPAL SOLID WASTE LANDFILL UNITS BY TYPE OF RUN-ON/RUN-OFF SYSTEM AND AGE OF UNIT

Age of Unit (years as of 1986)	Diversion Berms	Collection/ Sedimentation Ponds	Diversion Ditches	Other System	No System
Less than 5	817	424	912	113	437
5 - 10	409	215	553	141	390
11 - 15	446	237	533	75	505
16 - 20	217	86	313	28	390
More than 20	342	160	464	71	726
Unknown	53	27	52	2	36

SOURCE: Reference 3.

Table 4-33. NUMBER OF CLOSED MUNICIPAL SOLID WASTE LANDFILL UNITS BY TYPE OF RUN-ON/RUN-OFF SYSTEM AND AGE OF UNIT

Age of Unit (years as of 1986)	Diversion Berms	Collection/ Sedimentation Ponds	Diversion Ditches	Other System	No System
Less than 5	256	93	176	18	200
5 - 10	328	106	411	45	471
11 - 15	264	53	306	79	232
16 - 20	118	28	131	31	88
More than 20	204	34	169	60	171
Unknown	23	3	3	0	46

SOURCE: Reference 3.

Table 4-34. NUMBER OF ACTIVE MUNICIPAL SOLID WASTE LANDFILLS WITH GAS MONITORING DETECTION OR RECOVERY SYSTEMS BY AGE OF FACILITY

Age of Facility (years as of 1986)	Monitoring or Detection System	Recovery System	Total Landfills
Less than 5	49	10	59
5-10	72	9	81
11-15	90	40	130
16-20	58	14	72
More than 20	100	45	145
Unknown	32	5	37

SOURCE: Reference 3.

The layout of the wells depends on many factors, including the results of a field testing program, the end use of the landfill surface, and the purpose of the collection system. Testing at a landfill will indicate which areas of the landfill might provide the most gas of good quality for a recovery system.

Processing -- Before the gas can be sold or used, it must be purified. A processing unit is used to treat the gas to certain specifications, depending on the grade desired (medium or high Btu gas). For medium Btu gas, processing requires removal of particulates and water. For high Btu gas, processing requires removal of particulates, water, carbon dioxide, and most trace components. According to the literature, typical gas processing rates are from 0.001 to 0.008 cubic meter per kilogram dry refuse per year.

Enhancement -- Enhancing landfill gas production involves accelerating gas production and increasing the total amount of gas produced. In general, enhancement of landfill gas production is possible through several techniques: (1) moisture can be added and circulated through the landfill, (2) nutrients and bacteria can be introduced with anaerobically digested sewage sludge, (3) the pH can be adjusted with a buffer such as calcium carbonate or certain waste products, and (4) particle size can be reduced by shredding the incoming refuse. The technical and economic feasibility of increasing gas yield with these techniques remains to be determined by large-scale field tests.[23]

Cover and Closure Characteristics

The final cover is installed when a landfill has reached the end of its useful life. A key element in site closure, the final cover, seals the fill material for environmental protection and allows the land to be used for some benefit (farming, recreation, development, etc.). The major elements of cover design and analysis include determination of allowable percolation, water balance analysis, soil and membrane selection, compaction and placement, surface slope, and drainage. Although preventing water infiltration, which contributes to leachate generation, is the major focus of landfill cover design, covers can be designed to permit water flow for gas enhancement and chemical stabilization.

The MSWLF Survey provided information on the number of MSWLFs using various types of cover materials. Table 4-35 presents the number of closed, active, or planned MSWLFs using various types of cover materials. The survey results indicate that soil, clay, and topsoil are the most predominant type of cover materials for MSWLFs.

Table 4-35. NUMBER OF MUNICIPAL SOLID WASTE LANDFILLS BY COVER TYPE AND OPERATING STATUS

Cover Type	Number of Municipal Solid Waste Landfills		
	Closed	Active	Planned
Soil	1,598	3,278	1,672
Sand or Gravel	370	939	350
Recompacted Clay	1,022	2,132	1,093
Synthetic Membrane	44	110	79
Topsoil	1,053	2,448	1,243
Other	310	339	346
Unknown	89	393	146

SOURCE: Reference 3.

Location Factors

The topography, hydrogeology, ecology, and demography of a landfill site may influence the potential for leachate generation (through precipitation and waste generation), the dilution potential of the area surrounding the waste site, and the potential for human or environmental exposure. The Subtitle D census provided geographical data on MSWLFs, and EPA has compiled a list of MSWLFs from these data.[29] From this list it can be concluded that MSWLFs are located in all hydrogeological settings in the United States. No census data were available for industrial or demolition debris landfills concerning location characteristics of different facilities or numbers of landfills using location factors in their designs. A discussion of State and territorial location requirements is presented in Chapter 5.

Data on the location characteristics of MSWLFs also were provided by the MSWLF Survey. Table 4-36 presents the number of MSWLFs located in floodplains, wetlands, karst terrain, or below seasonal-high water tables. The data indicate that a small percentage of landfills are located in these areas. Table 4-37 presents the same location data for Federally-owned MSWLFs and indicates a similar distribution. Table 4-38 presents the number of MSWLFs according to age that fall in these categories.

Data on the predominant soil type underlying MSWLFs were available from the MSWLF Survey and are presented in Table 4-39. The survey results indicate that a majority of MSWLFs are located over clay (35 percent) or sandy clay (21 percent).

Table 4-36. NUMBER OF MUNICIPAL SOLID WASTE LANDFILLS IN SELECTED TERRAINS

Location Criteria	Number of Landfills	Percentage of Total Landfill Establishments[a]
100-Year Floodplains	766	13
Wetlands	334	6
Karst Terrain	231	4
Below Seasonal-High Water Table	429	7

SOURCE: Reference 3.

[a] Total of percentages is greater than 100 because some landfills overlap location criteria.

Table 4-37. NUMBER OF FEDERALLY-OWNED MUNICIPAL SOLID WASTE LANDFILLS IN SELECTED TERRAINS

Location Criteria	Number of Federally-Owned Municipal Solid Waste Landfills	Percentage of Total Municipal Solid Waste Landfill Establishments[a]
100-Year Floodplains	13	7
Wetlands	13	7
Karst Terrain	6	3
Below Seasonal-High Water Table	13	7

SOURCE: Reference 3.

[a] Total of percentages is greater than 100 because some landfills overlap location criteria.

Table 4-38. NUMBER OF MUNICIPAL SOLID WASTE LANDFILLS BY LOCATION CRITERIA AND AGE OF FACILITY

Age of Facility (years as of 1986)	Location Criteria			
	100-Year Floodplains	Wetlands	Karst Terrain	Under Seasonal-High Water Tables
Less than 5	81	8	21	31
5 - 10	140	34	55	57
11 - 15	164	49	63	65
16 - 20	87	29	23	68
More than 20	292	206	67	198
Unknown Age	2	8	2	10
Total	766	334	231	429

SOURCE: Reference 3.

Table 4-39. NUMBER OF MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS BY UNDERLYING PREDOMINANT SOIL TYPE

Soil Type	Number of Landfills	Percentage of Landfills
Clayey Sand	547	9
Sand	822	14
Clay	2,100	35
Sandy Clay	1,238	21
Silt	214	4
Other	1,054	17

SOURCE: Reference 3.

The MSWLF Survey provided data on the horizontal flow rate of ground water in the uppermost aquifer beneath each MSWLF. Approximately 17 percent of establishments are located over aquifers with horizontal flow rates of more than 10^{-5} cm/sec but most respondents (60 percent) do not know the horizontal flow rate. The results are presented in Table 4-40.

Table 4-40. NUMBER OF MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS BY HORIZONTAL FLOW RATE IN GROUND WATER

Horizontal Flow Rate (cm/sec)	Number of Landfills	Percentage of Total Landfill Establishments[a]
10^{-7} - 10^{-6}	170	3
10^{-6} - 10^{-5}	146	2
10^{-5} - 10^{-4}	297	5
10^{-4} - 10^{-3}	300	5
More than 10^{-3}	404	7
Unknown	3,566	60

SOURCE: Reference 3.

[a] Overall response rate for this table is 81 percent.

The MSWLF Survey also provided data on the sources of hydrogeologic and water source data available to these facilities. Tables 4-41 and 4-42 present these data. Both tables indicate that MSWLF owners and operators commonly use "best estimates" to develop water source and hydrogeologic data for their facilities. Site-specific studies are performed for only 17 percent (water source studies) to 28 percent (hydrogeologic studies) of all MSWLFs.

Table 4-41. SOURCE OF HYDROGEOLOGIC INFORMATION PROVIDED FOR MUNICIPAL SOLID WASTE LANDFILL SURVEY

Source of Data	Number of Landfills	Percentage of Total Landfill Establishments[a]
Site-Specific Study	1,683	28
Regional Report	1,070	18
State Agency	827	14
No Data ("Best Estimate")	4,033	67

SOURCE: Reference 3.

[a] Total of percentages is greater than 100 percent since some landfills reported more than one data source.

Table 4-42. SOURCE OF WATER INFORMATION PROVIDED FOR MUNICIPAL SOLID WASTE LANDFILL SURVEY

Source of Data	Number of Landfills	Percentage of Total Landfill Establishments[a]
Site-Specific Study	1,003	17
Local Water Department	590	10
No Data ("Best Estimate")	3,874	64
Other	846	14

SOURCE: Reference 3.

[a] Total of percentages equals more than 100% since some landfills reported more than one data source.

Landfill Operation and Maintenance

The operation and maintenance of a landfill can be viewed as an ongoing construction project. As with any construction effort, it proceeds according to detailed plans and is accompanied by appropriate equipment, materials, and personnel. Characteristics addressed in this subsection include landfill employees, equipment, daily operations, waste restrictions, and emergency preparedness and contingency plans. Most of this discussion pertains to MSWLFs, because little information is available on other landfill types.

Employees

The variety of positions at MSWLFs depends on the size of the operation. For small sites (50 to 70 tons per day (TPD)), a single full-time operator may be able to satisfactorily operate equipment, record waste quantities, and perform administrative and maintenance functions. Larger sites may require more positions, including one or more of the following: supervisor, equipment operator, check station attendant, mechanic, and laborer. As a general rule, one employee is needed per 70 tons per day of waste received.[26] However, requirements are site-specific, and the number of employees may be affected by the size of the landfill (waste received), the operating method (trench, area, shredding, balefill), site characteristics, and operating hours. No data were available on the number of employees used per landfill.

Equipment

Equipment at Subtitle D landfills serves three basic functions: (1) handling waste, (2) excavating soil and handling cover soil, and (3) performing support functions. Handling of solid waste at a landfill site resembles earth-moving, but differences exist that require consideration. Solid waste is less dense, more compressible, and more heterogeneous than earth. Spreading a given volume of solid waste requires less energy than spreading an equal volume of soil. Support equipment may be required to perform such tasks as road construction and maintenance, dust control, fire protection, and possibly assistance in waste unloading operations.

Equipment functions and performance specifications vary with the size of the landfill. Except large landfills, the same piece of equipment normally performs all functions. Additional equipment may be on hand for busy times and when other equipment is out of service.[26] No data were available on the number and types of equipment used per landfill.

Daily Operations

Daily MSWLF operations include fill operations, fill-related tasks, and other general procedures. The two basic fill methods are trench and area. Trench operations use a prepared excavation that confines the working face between two side walls. The area method does not use extensive surface preparation; therefore, the width of the working face is limited only by the site boundaries. Some landfills use a combination of both methods at different locations or times. Other methods involve the preparation of wastes by shredding or baling, but these methods are essentially variations of trench and area methods.

Procedures dependent on the landfilling method include site preparation, traffic flow and unloading, and compaction and covering. General operational procedures are as follows: environmental control practices (siltation and erosion, mud, dust, vectors, odors, noise, aesthetics, birds, litter, fires); inclement weather practices; and ongoing engineering practices (site preparation, road maintenance). No data were available on any of these daily operating procedures of landfills.

Waste Restrictions

Waste restrictions vary widely with the design and operation criteria of the individual landfill. Table 4-27 indicates that about 40 percent of all landfills identified in the census impose some type of restrictions on the wastes they receive. Municipal solid waste landfills have these restrictions more often than any other landfill type.

The numbers of MSWLFs (distributed by landfill age) that do not accept various types of waste and use segregated disposal areas are presented in Tables 4-43 and 4-44, respectively. The data indicate that household waste and construction/demolition waste are accepted by nearly all MSWLFs. However, these wastes are segregated from the general waste stream at MSWLFs more often than any other waste type.

Emergency Preparedness and Contingency Plans

Anticipating the operational problems and addressing contingencies in the operation plan may reduce risks to human health and the environment. Some of the major potential problems at MSWLFs include fires, inclement weather, equipment failure, and personnel shortages.

There are many potential sources of fires at landfills. These include receipt of hot wastes such as incinerator ash, sparks from vehicles igniting flammable wastes, and vandalism. Many facilities employ tight security to spot hot or highly flammable wastes and direct them to specific areas to be wetted down or smothered with soil or water. When fires do occur, they are usually dug out and smothered with soil and/or water or smothered by placing damp soil on the surface of the fill. Several particularly large facilities have a fire department on-site.

Equipment failure is common at landfills due to high usage. Contingency plans may include well-documented procedures for repairs, either with on-site mechanics or by outside means, having redundant equipment at the fill, or borrowing or leasing from allied agencies (e.g., public works, contractors). Additional personnel may be required for seasonal or other peak waste-receiving times or to temporarily replace sick or injured workers. Employees may be trained to perform multiple tasks, and procedures for labor overhires can be outlined in advance and initiated quickly when

Table 4-43. NUMBER OF MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS NOT ACCEPTING VARIOUS WASTE TYPES BY AGE OF FACILITY

Waste Type	Number of Municipal Solid Waste Landfill Establishments By Age Of Facility (years as of 1986)					Total Municipal Solid Waste Landfill Establishments Per Waste Type [a,b]
	Less than 5	5 - 10	11 - 15	16 - 20	More than 20	
Household Waste	0	0	0	0	7	7
Commercial Waste	0	0	20	26	20	65
SQG Waste	210	348	507	292	666	2,022
Bulk Liquids (not containerized)	188	360	601	294	710	2,152
Drummed/Containerized Waste	195	333	543	274	731	2,075
Asbestos-Containing Waste Materials	143	283	359	171	496	1,451
Construction/Demolition Wastes	13	52	73	49	73	260
Industrial Process Wastes	93	245	216	187	445	1,185
Infectious Wastes	187	339	542	268	650	1,986
Municipal Incinerator Ash	112	273	396	245	551	1,577
Other Incinerator Ash	105	260	365	227	517	1,475
Recyclable Wastes	50	146	211	85	286	778
Sewage Sludge	133	235	369	201	522	1,460
Other	0	2	0	7	0	8

SOURCE: Reference 3.

[a] Includes other landfills of unknown age.

[b] These totals are correct. Table entries have been rounded and may not add to their respective totals.

Table 4-44. NUMBER OF MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS USING SEPARATE DISPOSAL AREAS FOR VARIOUS WASTE TYPES BY AGE OF FACILITY

Waste Type	Number of Municipal Solid Waste Landfill Establishments by Age of Facility (years as of 1986)					Total Municipal Solid Waste Landfill Establishments Per Waste Type[a,b]
	Less Than 5	5 - 10	11 - 15	16 - 20	More Than 20	
Household Waste	125	212	289	175	449	1,251 (21%)
Commercial Waste	47	141	182	57	244	671 (11%)
SQG Waste	2	16	26	0	35	80 (1.3%)
Bulk Liquids (not containerized)	7	42	49	15	37	149 (2.5%)
Drummed/Containerized Waste	7	54	52	13	8	134 (22%)
Asbestos-Containing Waste Materials	23	77	102	66	141	410 (7%)
Construction/Demolition Wastes	177	208	336	205	546	1,472 (2.4%)
Industrial Process Wastes	0	45	62	8	68	183 (3%)
Infectious Wastes	2	36	21	7	13	78 (1.3%)
Municipal Incinerator Ash	7	18	21	2	31	78 (1.3%)
Other Incinerator Ash	13	31	42	7	44	136 (2.2%)
Recyclable Wastes	67	103	224	132	277	803 (13%)
Sewage Sludges	34	93	130	63	146	466 (8%)
Other	52	101	226	88	226	692 (11%)

SOURCE: Reference 3.

[a] Includes landfills of unknown age.

[b] Percentage is relative to total number of MSWLF establishments (6,034).

needs arise. No data were available concerning the use and elements of emergency preparedness and contingency plans.

Environmental Monitoring at Landfills

Landfill monitoring is used to measure changes in the environment that occur as a result of disposal. Environmental monitoring design may vary, depending on landfill design, operation, and maintenance characteristics; wastes received; and location. Monitoring for any given landfill may measure ground and surface water, and air and methane. Monitoring of these media and specific test parameters are discussed below.

Table 4-45 presents data on the number of active landfills with monitoring systems identified in the census and by the MSWLF Survey. Ground water is the most frequently monitored medium, and air is the least.

Ground-Water Systems/Parameters

Subtitle D census data reported in Table 4-45 show 3,134 landfills (19 percent) monitor ground water. Of these, 2,331 are MSWLFs. The MSWLF Survey estimates that 2,141 MSWLFs monitor ground water.

Table 4-46 presents data from the MSWLF Survey on the distribution of MSWLFs with ground-water monitoring systems according to landfill age. The data indicate many more new landfills than old landfills are monitoring ground water. Similar data from the MSWLF Survey are presented in Table 4-47 for Federally-owned MSWLFs.

Devices -- Monitoring equipment may be classified as wells with the capacity to sample at a single depth (single-screened wells), multisampling wells for sampling at different depths (multiprobe wells or well clusters); and piezometers, which are designed to obtain samples using airlift methods (airlift samplers). No data are available on the number of facilities using different devices.

Locations -- Ground-water monitoring systems are very site-specific. Landfill size and site hydrogeology are factors that dictate the actual number of installed wells. The spacing and depths of monitoring wells depend on the particular pattern of ground-water flow, making it extremely difficult to specify aggregate statistics for this area.

Table 4-45. NUMBER OF ACTIVE LANDFILLS WITH MONITORING SYSTEMS[a]

Landfill Type	Ground-Water Monitoring	Surface-Water Monitoring	Air Emissions Monitoring	Methane Monitoring
Municipal solid waste	2,331 (25%) 2141[b] (35%)	1,100 (12%) 912[b] (15%)	358 (3.7%) 161[b] (2.7%)	427 (4.6%) 401[b] (6.6%)
Industrial waste	626 (18%)	230 (6.7%)	80 (2.3%)	63 (1.8%)
Demolition debris only	135 (5.2%)	69 (2.7%)	7 (0.3%)	8 (0.3%)
Other	42 (4.1%)	16 (1.6%)	0	0
Total[c]	3,134 (19%)	1,415 (8.9%)	445 (2.7%)	498 (3.0%)

SOURCE: Reference 1.

[a] Percentages are relative to approximately 9,300 (for census data).

[b] Percentage are relative to approximately 6,600 (for survey data).

[c] These are the correct totals. Table entries have been rounded and may not add to their respective totals.

Table 4-46. NUMBER OF MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS WITH GROUND-WATER AND SURFACE WATER MONITORING SYSTEMS BY AGE OF FACILITY

Age of Facility (years as of 1986)	Number of Municipal Solid Waste Landfills with Ground-Water Monitoring	Number of Municipal Solid Waste Landfills with Surface Water Monitoring
Less than 5	279	97
5 - 10	391	182
11 - 15	637	240
16 - 20	293	136
More Than 20	493	238
Unknown	48	19
All Ages[a]	2,141	912

SOURCE: Reference 3.

[a] These are the correct totals. Table entries have been rounded and may not add to their respective totals.

Table 4-47. NUMBER OF FEDERALLY-OWNED MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS WITH GROUND-WATER AND SURFACE WATER MONITORING SYSTEMS BY AGE OF FACILITY[a]

Age of Facility (years as of 1986)	Number of Municipal Solid Waste Landfills with Ground-Water Monitoring	Number of Municipal Solid Waste Landfills with Surface Water Monitoring
Less Than 20	29 (15%)	2 (1.0%)
21 - 30	6 (3%)	6 (3%)
31 - 40	6 (3%)	6 (3%)
More Than 40	13 (7%)	6 (3%)
All Ages[b,c]	55 (21%)	20 (10%)

SOURCE: Reference 3.

[a] Percentages are relative to total of 193 Federally-owned MSWLFs.

[b] These are the correct totals. Table entries have been rounded and may not add to their respective totals.

[c] Numbers include landfills of unknown age.

Surface Water Systems/Parameters

Surface water monitoring is often implemented as a component of a total monitoring network. The proximity of a solid waste landfill to surface water and local drainage patterns may determine whether surface water monitoring is necessary. Indicator parameters and analytical methods used for surface water samples are usually consistent with those for ground-water testing.

Subtitle D census results concerning the extent of surface water monitoring for landfills are presented in Table 4-45. Approximately 9 percent of all landfills identified in the census have surface water monitoring systems. Municipal solid waste and industrial landfills have the highest percentage of surface water monitoring system use (12 and 7 percent, respectively). The MSWLF Survey indicates that 15 percent of MSWLFs monitor surface water (see Table 4-40).

Table 4-47 contains data from the MSWLF Survey on the distribution of MSWLFs with surface water monitoring systems according to landfill age. The estimates indicate many more new landfills than old landfills monitoring surface water.

Air and Gas Systems/Parameters

Gas sampling devices usually consist of simple, inexpensive gas probes. The probe is usually polyethylene, copper, or stainless steel tubing. Due to the small diameter of probes, a series of these devices can be situated at various depths within a single hole. The sample collection technique depends upon the type of sampling probe installed. Most frequently, a portable meter is used to monitor methane gas. The sampling frequency often depends upon the frequency of monitoring in other media. The estimated rate of movement of gas in particular soil may be useful for developing sampling frequencies.

Data concerning the extent of ambient air or methane monitoring for Subtitle D waste landfills are presented in Table 4-45. The Subtitle D census determined that few landfills have air or methane monitoring systems (about 3 percent for both). This is supported by MSWLF Survey data, also presented in Table 4-45. The MSWLF Survey estimated that 161 (2.7 percent) MSWLF establishments monitor air emissions and 401 (6.6 percent) monitor methane gas. The distributions by age of the landfills that monitor air emissions and methane are presented in Tables 4-48 and 4-34, respectively. Table 4-49 presents similar data for Federally-owned MSWLFs and indicates that very few of the 193 Federal MSWLFs employ air emissions or gas monitoring.

Table 4-48. NUMBER OF MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS WITH AIR MONITORING SYSTEMS BY AGE OF FACILITY

Age of Facility (years as of 1986)	Number of Municipal Solid Waste Landfills with Air Emissions Monitoring
Less than 5	21
5 - 10	45
11 - 15	37
16 - 20	18
More than 20	37
All Ages	161

SOURCE: Reference 3.

4.1.4 ANALYSIS OF ENVIRONMENTAL AND HUMAN HEALTH IMPACTS AT LANDFILLS

Aggregate data collected in the Subtitle D census and detailed case studies are used to analyze the environmental and human health impacts at Subtitle D landfills. The aggregate census data can

Table 4-49. NUMBER OF FEDERALLY-OWNED MUNICIPAL SOLID WASTE LANDFILL ESTABLISHMENTS WITH AIR AND METHANE MONITORING SYSTEMS BY AGE OF FACILITY

Age of Facility (years as of 1986)	Number of Federally-Owned Municipal Solid Waste Landfills with Air Monitoring	Number of Municipal Solid Waste Landfills with Gas Monitoring
Less than 5	0	0
5 - 10	6	6
11 - 15	2	16
16 - 20	0	0
More than 20	0	0

SOURCE: Reference 3.

be used to correlate different types of contaminant problems with different landfill categories and to indicate the extent of these problems across the universe of landfills. The EPA has also conducted a risk analysis on MSWLFs to support both the Subtitle D study effort and the development of revisions to the Subtitle D criteria. The results of this analysis are included in this subsection under ground water.

Table 4-50 presents the relevant Subtitle D census data for ground-water, surface water, and air impacts at Subtitle D landfills. This table also presents statistics on the number of State landfill inspections conducted and violations detected in 1984 and on the number of landfills with monitoring systems in place (by medium).

The following discussion presents the available aggregate and case study information for ground-water, surface water, and air contaminant impacts. A general description of the solid waste disposal problem on Indian lands follows this discussion.

Ground Water

Census Data

The census data in Table 4-50 indicate that violations of State ground-water protection standards occurred at 720 Subtitle D landfills, 586 of which were at MSWLFs. Fewer violations were reported for other landfill types, but this is most likely because fewer industrial and demolition debris landfills monitor the ground water or are inspected by the State more than once a year. The

Table 4-50. AGGREGATE DATA RELATING TO ENVIRONMENTAL CONTAMINATION AT LANDFILLS IN 1984

	Subtitle D Landfill Type				Total Landfills Per Category
	Municipal Solid Waste	Industrial Waste	Demolition Waste	Other	
Total Active Facilities	9,284	3,511	2,591	1,030	16,416
Number of Facilities With at Least One Violation					
Ground-water contamination	586	111	16	7	720
Surface-water contamination	660	50	42	6	758
Air contamination	845	18	33	54	950
Methane control deficiencies	180	8	0	1	189
State Inspection at Least Once Each Year[a]	6,708	2,653	1,548	631	11,540
Facilities With Monitoring					
Ground water	2,331	626	135	42	3,134
Surface water	1,100	230	69	16	1,415
Air emissions	358	80	7	0	445
Methane	427	63	8	0	438

SOURCE: Reference 1.

[a] These data include numbers cited by States or territories for frequencies ranging from once a year to more than four times a year. The category excludes less frequent inspections and entries under the questionnaire category of "other."

number of reported violations is an imperfect measure of environmental impacts because (1) "violations" may be defined differently among States and territories, (2) many violations may go unreported due to inspection or monitoring inadequacies, and (3) multiple violations can occur at a facility.

Case Studies

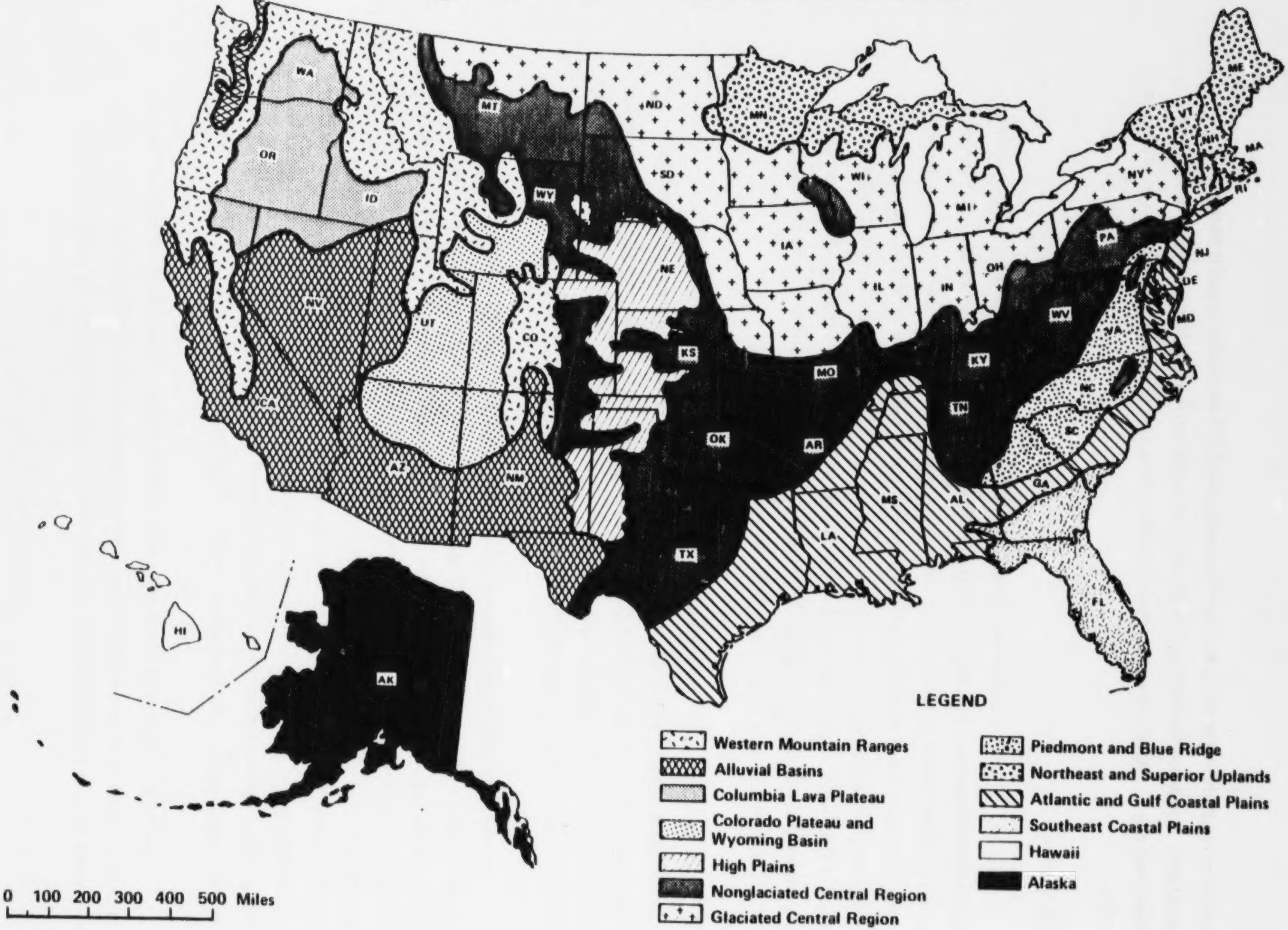
To date, 163 MSWLFs have been identified for which environmental impacts and threats to human health have been documented.[30] The sources for this information included MSWLF case studies prepared by and for the EPA, literature search of newspapers and journals, and a telephone survey. The case studies were chosen from eight States that represent a variety of hydrogeologic settings and encompass all 11 of the ground-water regions of the continental United States, as shown in Figure 4-3. In addition, the States represent a variety of demographic settings ranging from major urban areas to rural areas. Sites were selected using the above criteria and availability and completeness of data, particularly monitoring data.

The literature search was conducted to obtain information documenting health or environmental impacts resulting from MSWLFs. A telephone survey of eight States also was conducted. These States were selected because they indicated in the 1984 State Subtitle D Program Questionnaire that they had case studies available. These case studies are good examples of problems that can occur at poorly designed and operated landfills.

Ground-water quality was adversely affected at 146 sites. Ninety of the sites had contaminated on-site ground water and 56 of the sites had contaminated off-site ground water. The impacts identified range in severity from simply elevated levels of various constituents in on-site ground water to the contamination of major aquifers and/or productive well fields. Thirty-five sites were documented to have adversely affected drinking water resources and three other sites pose a threat to water supply systems. In 17 of these case studies alternative water supplies were necessary. As an example, one active MSWLF in Florida contaminated a square mile of a sole source aquifer and closed a major community well field. Elevated levels of organics, including pesticides, and metal contaminants have been found in ground water at many of these sites.

Regardless of the degree of ground-water contamination, certain factors were common to these cases. Most were located within eight feet of the ground-water table, underlain by highly permeable soils, or engineered without an effectively impermeable liner. In addition to these

Figure 4-3. GROUND-WATER REGIONS OF THE UNITED STATES



generic factors, the ground-water contamination appeared to be more severe in areas characterized by higher net infiltration rates and ground-water flow rates.

The analysis of case study information identified several factors that in various combinations determine failure at a particular facility. These factors include the following:

- the age of the landfill;
- the location (e.g., climate , depth to ground water, soil permeability, and leachate migration potential); and
- the engineering design (e.g., liner use, run-on/run-off control systems, leachate collection systems) and design/operation practices.

The representativeness of the information to the universe of MSWLFs is unknown, and it is not possible to isolate the specific factors responsible for each failure. Another potential factor that may cause detrimental impacts is the characteristics of the waste itself. However, the waste types disposed of at the MSWLFs reviewed for this study were not available to determine waste characterization as a specific factor.

Municipal Solid Waste Landfill Survey Data

Results from the MSWLF Survey provided data on the population using ground water for drinking in the areas surrounding MSWLFs. The survey indicates that approximately 46 percent of MSWLFs are located within one mile of the drinking water wells, while 54 percent are not within one mile of any drinking water well. Table 4-51 presents the percentage of MSWLFs located within one mile of an active drinking well.

Risk Analysis

The Subtitle D MSWLF universe consists of a diverse group of facilities that occur in a wide variety of environmental settings. Hundreds of factors affect the nature, extent, and severity of environmental impacts from these facilities. To identify and evaluate some of the most important factors, EPA developed the Subtitle D Risk Model. The model concentrates on ground water as the environmental medium of concern; surface water and air-related impacts were not addressed. This model couples information from the Office of Solid Waste case studies, MSWLF Survey, and other

Table 4-51. NUMBER OF MUNICIPAL SOLID WASTE LANDFILLS WITHIN ONE MILE OF ACTIVE DRINKING WATER WELLS

Distance (meters) to Nearest Well (public or private)	Percentage of Landfills
10	2.4
60	4.4
200	6.0
400	12.7
600	5.0
1,000	9.8
1,500	5.3
None within 1 mile	54.4

SOURCE: Reference 3.

sources, with a series of mathematical formulations of engineering, physiochemical, hydrologic, toxicologic, and socioeconomic processes that govern impacts.

Although the Subtitle D Risk Model has been neither peer reviewed nor verified, EPA has used it in its preliminary form to help analyze human health and resource impacts associated with ground-water contamination at Subtitle D MSWLFs under the current set of criteria (i.e., baseline conditions). The baseline facility that has been analyzed consists of a new, unlined facility with a vegetative cover. Since the majority of existing facilities are unlined, this analysis roughly estimates risks posed by existing facilities.

There are several important caveats to the risk analysis results presented in this section. The risk and resource damage modeling includes considerable uncertainty. The model components that introduce the most uncertainty are those that predict leachate quality for trace organics, and the human health risks resulting from exposure to toxic substances (i.e., the dose-response model).

In addition, the risk results are based on the current distribution of drinking water wells near MSWLFs (from the MSWLF survey). No attempt was made to predict how that distribution will change with the siting of new MSWLFs. The model only estimates risk for facilities with drinking water wells within one mile. Therefore, the model predicts that facilities with no wells within one mile pose no human health risk. This is a limitation of the model; EPA has not assumed that these facilities actually pose no ground-water risks.

The following presents an overview of the risk model methodology and then discusses the baseline human health and resource damage impacts, weighted to reflect the total population of 6,034 MSWLFs.

The Subtitle D Risk Model Methodology--The Subtitle D Risk Model builds directly on the Subtitle C Liner Location Risk and Cost Analysis Model,[31] and has adopted many of its basic characteristics. It is a dynamic model. For this analysis, 100 years of leachate release and up to 200 years of ground-water transport for each year's release were simulated.

Environmental fate and transport and dose-response relationships are modeled as deterministic processes, while containment system failure and some hydrologic events are considered stochastic phenomena. Some parameters can be varied over a wide range; for others, the user selects from specified, generic values.

The model includes a series of submodels that simulate pollutant release (liner failure and leachate quality submodels), fate and transport (unsaturated zone and saturated zone transport submodels), exposure, impacts (dose-response and resource damage submodels), and corrective action. For this analysis EPA assumed no corrective action occurs in the baseline. Brief summaries of each of these submodels, as they apply to the baseline facility, are presented in Appendix E.

Human Health Risk Results--A risk of 10^{-6} indicates that exposed individuals would bear a 1 in 1,000,000 chance of contracting cancer in their lifetime as a result of the exposure.

Across all 6,034 MSWLFs in the baseline, EPA estimates that average maximum exposed individual (MEI) risks over the 300-year modeling period range from approximately 10^{-4} to zero. Nearly 12 percent of all MSWLFs pose risks in the 10^{-5} to 10^{-6} range, approximately 6 percent fall within the 10^{-5} and 10^{-4} risk range, and a negligible 0.05 percent exceed 10^{-4}. Preliminary results from the MSWLF Survey indicate that about 54 percent of landfills have no drinking water wells within one mile of the facility boundary. The model, therefore, estimates that these facilities pose no human health risk. Another 6 percent have nearby wells but have no risk (MEI less than or equal to 10^{-10}) because no constituents reach the wells within the modeling period. The remainder of the facilities (22 percent) pose risks that are less than 10^{-6}. Figures 4-4 and 4-5 depict this baseline risk distribution. The principal constituents contributing to risk are vinyl chloride, 1,1,2,2-tetrachloroethane, and dichloromethane (methylene chloride).

Figure 4-4

DISTRIBUTION OF AVERAGE RISK

BASELINE

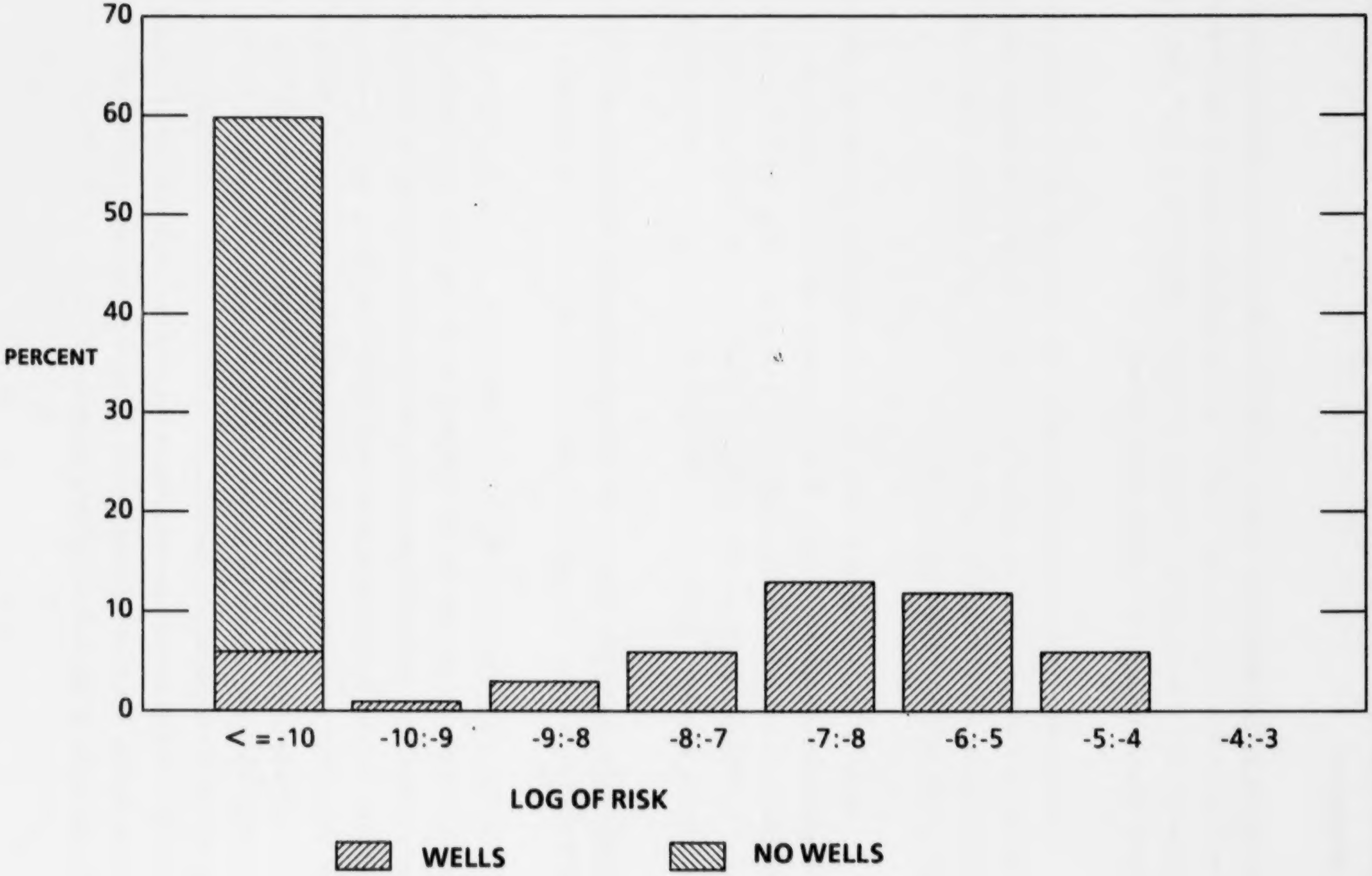
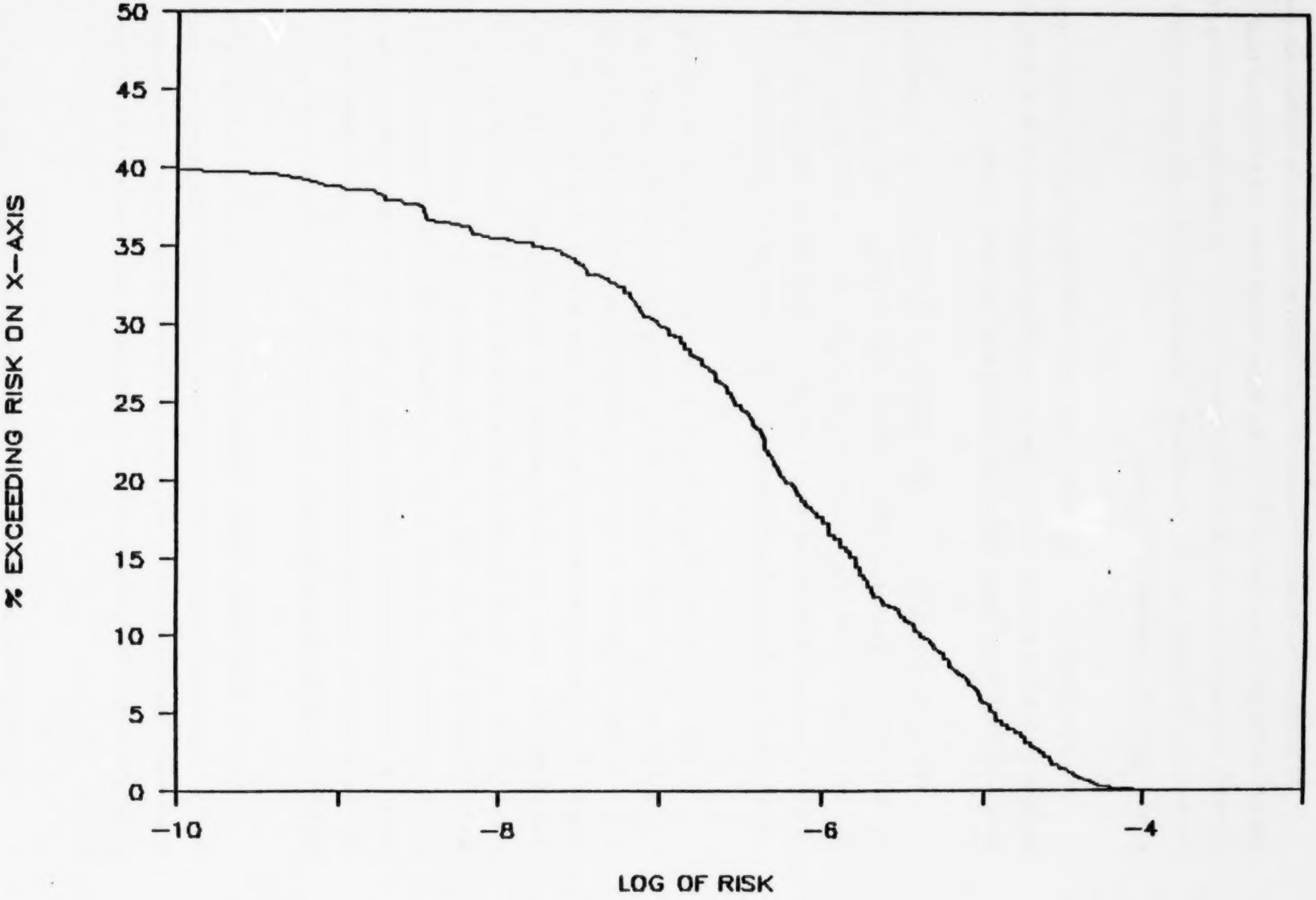


Figure 4-5

CUMULATIVE FREQUENCY OF AVERAGE RISK

BASELINE - ALL LANDFILLS



As future wells are located near existing MSWLFs (or new sites are located near current wells), the overall risk distribution will reflect the estimates for the subset (46 percent) of landfills that currently have wells within one mile of the facility boundary. For this subgroup of the population, the median risk is about 4.3×10^{-7}. In addition, nearly 40 percent of these landfills have a risk exceeding 10^{-6}, as presented in Figure 4-6.

For population risk, the Agency estimates that 0.0770 cancer case per year in the baseline can be expected over the 300-year modeling period (assuming there continues to be, in the future, no wells within one mile of 54 percent of the landfills and, therefore, no risk).

The results of the analysis identify several factors that are important in determining risk. However, risk is the result of a complex interaction among many factors (some of which have not been accounted for in this analysis) and, thus, no single factor is responsible for most of the variation. Some of the factors--constituent concentration in leachate, facility size, distance to nearest well, environmental setting, and aquifer characteristics--are discussed below.

Higher levels of contamination and, thus, risks may be associated with larger facilities which have a greater mass of waste. Figure 4-7 shows the distribution of risk by landfill size in unweighted terms (i.e., each landfill size/environmental setting/well distance combination is weighted equally) to focus on the relationship between risk and landfill size. In facilities handling 10 TPD) the model predicts that about 33 percent of the scenarios have risks that exceed 10^{-6}. This value increases to over 55 percent for 175-TPD facilities and nearly 64 percent for 750 -TPD facilities. Eight percent of the 10-TPD scenarios are predicted to have risks exceeding 10^{-5}, 22 percent of the 175-TPD scenarios exceed 10^{-5} and nearly 30 percent of the 750-TPD scenarios exceed 10^{-5}. Since only 5.5 percent of landfills fall into the 750-TPD category, the impact of these landfills on the overall distribution is small. The high percentage of small facilities (51 percent handle less than 18 TPD) in the MSWLF population tends to weight the overall distribution to lower risk levels.

All other factors held constant, risk decreases with increasing distance of wells from the facility. Contaminant concentrations diminish over distance due to degradation, dispersion, and attenuation. Results from the facility survey indicate that 54 percent of MSWLFs have no wells within one mile, 15 percent have wells within 300 meters, and 25 percent have wells within 500 meters.

If all exposure occurred at the facility boundary (assumed to be 10 meters from the landfill unit boundary), the baseline risk distribution would change significantly. Figure 4-8 compares the

Figure 4-6

CUMULATIVE FREQUENCY OF AVERAGE RISK

BASELINE - ONLY LANDFILLS WITH WELLS

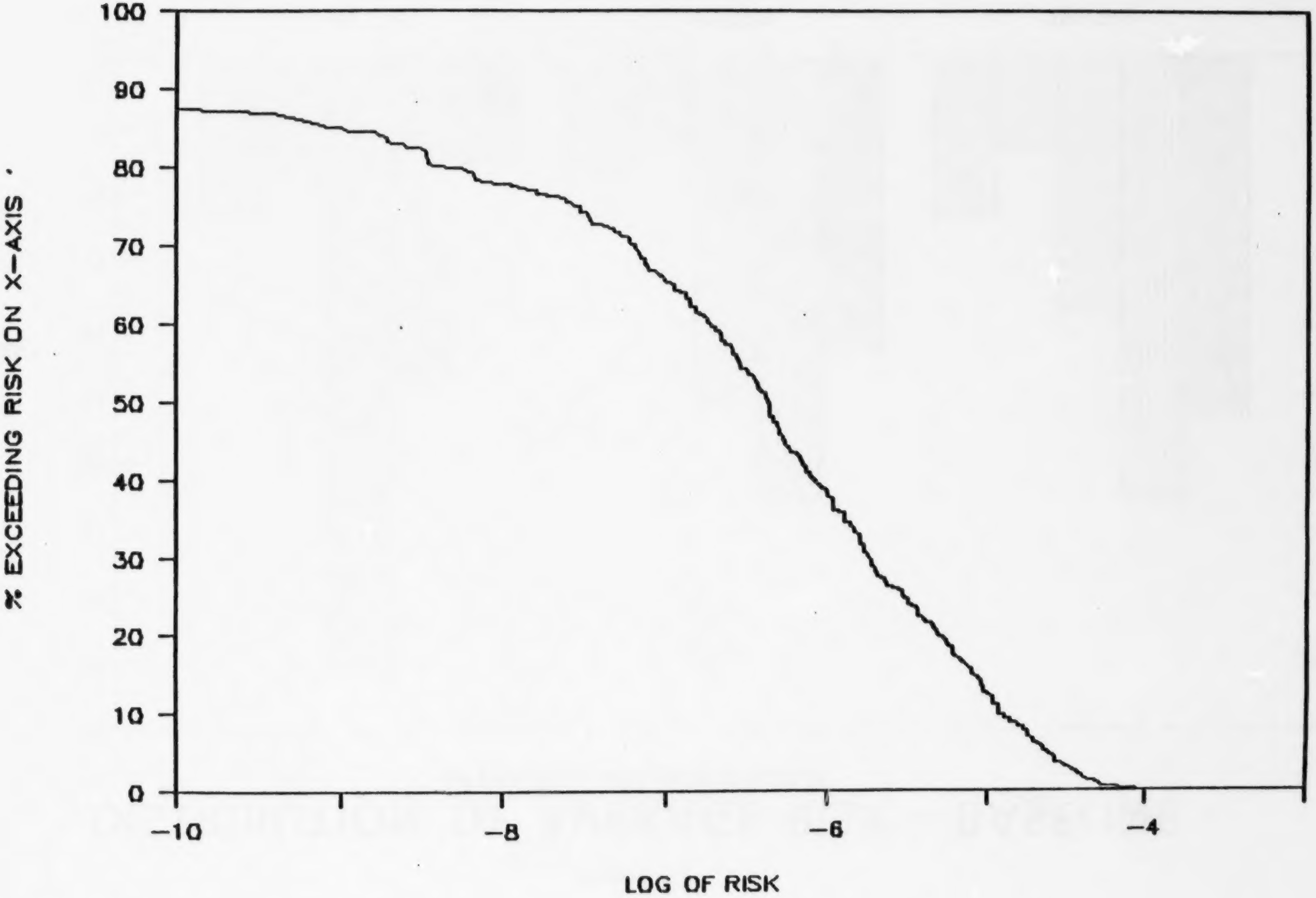


Figure 4-7

DISTRIBUTION OF AVERAGE RISK - BASELINE

BY LANDFILL SIZE (NORMALIZED)

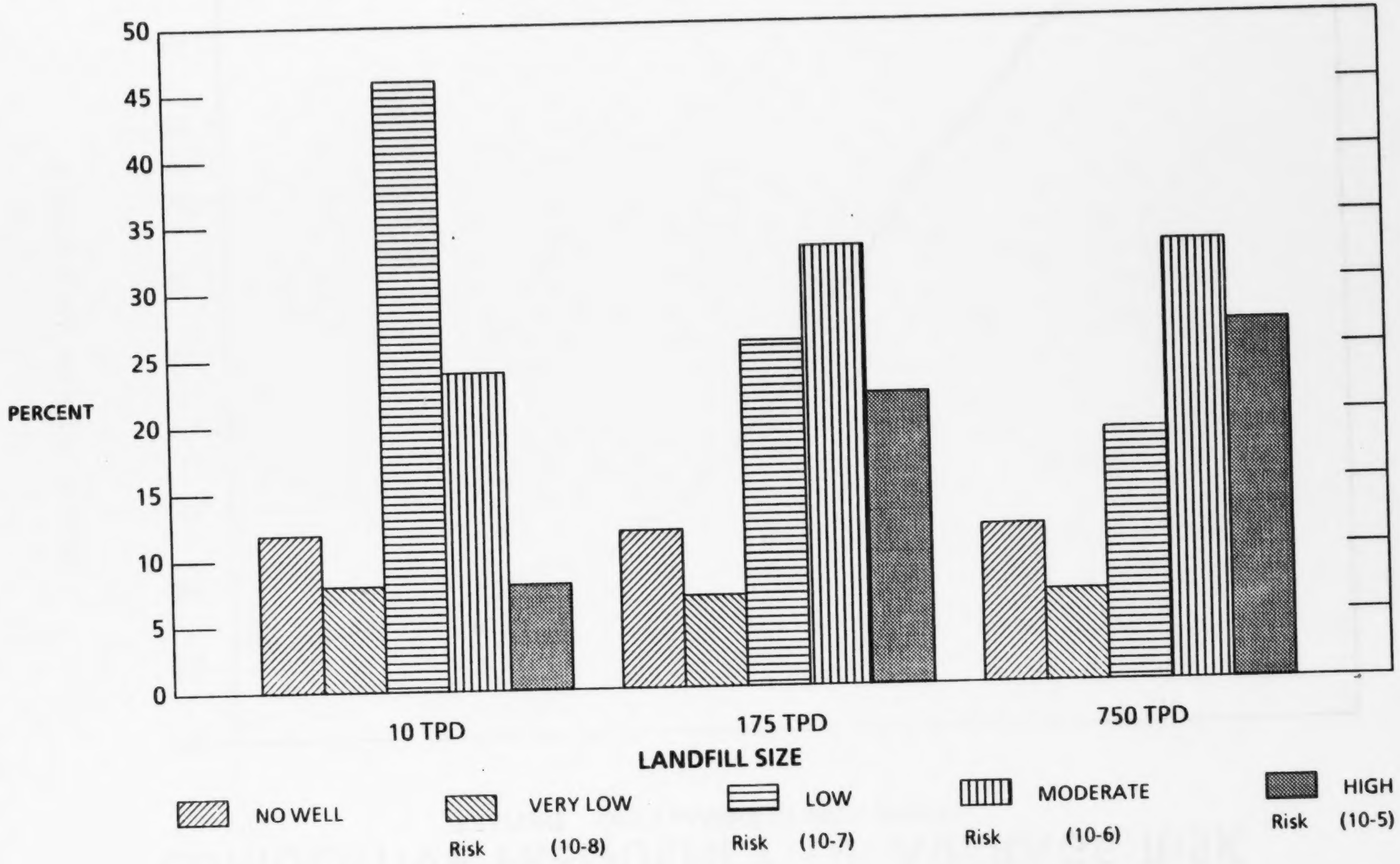
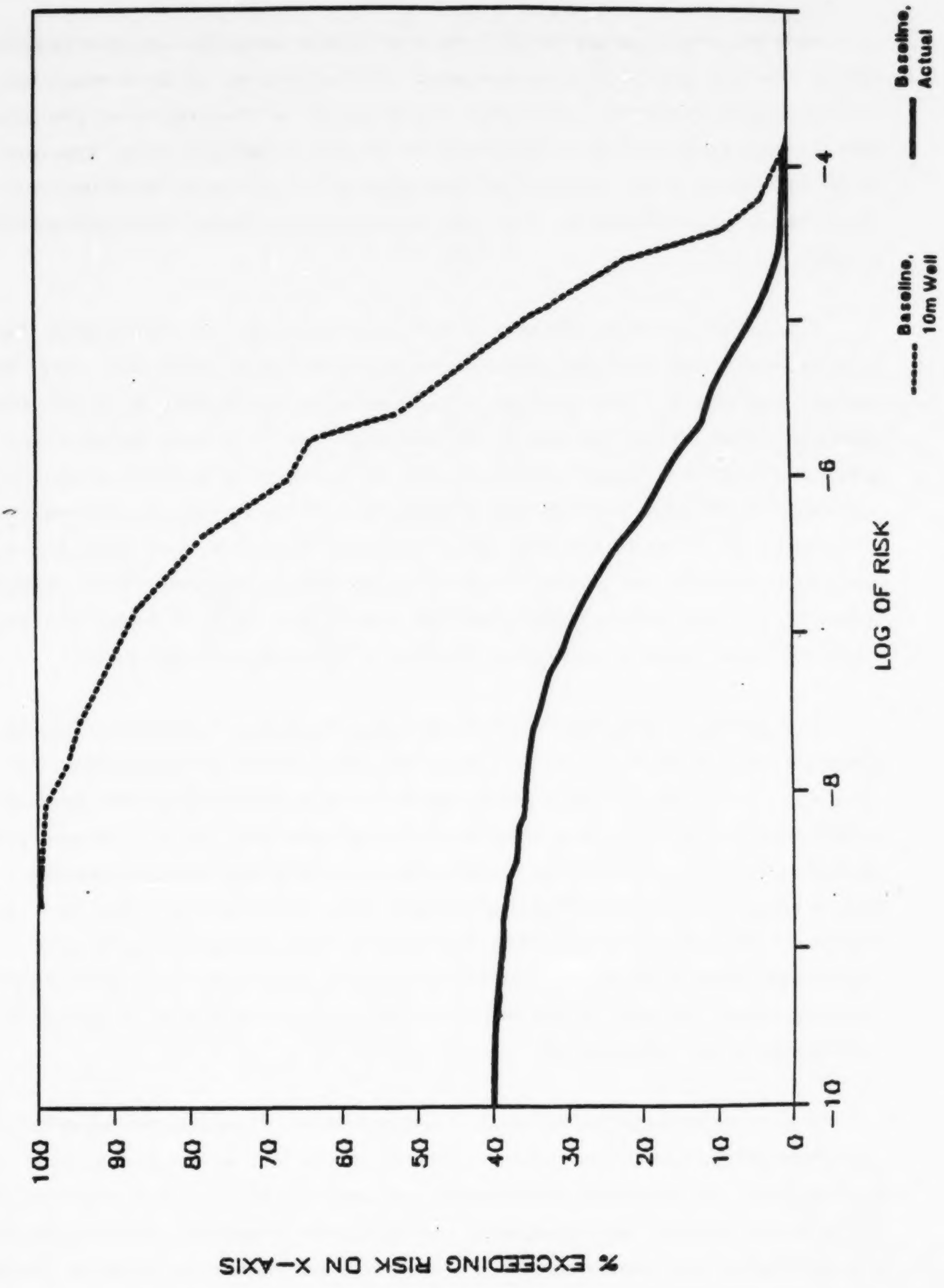


Figure 4-8

CUMULATIVE FREQUENCY OF AVERAGE RISK

BASELINE: ACTUAL VS 10M WELL



cumulative frequency of average individual risk at the 10-meter well to the cumulative frequency of risk using the existing well distribution as reported in the facility survey. While the model predicts that less than one-fifth of the landfills have risks exceeding 10^{-6} with the existing well distribution, over 50 percent exceed this risk level when exposure occurs at the facility boundary. Approximately 35 percent of MSWLFs have risks at the facility boundary, while only 6 percent posed these risks under the existing well distribution. Thus, the distribution of well distances has a significant effect on risk.

Figure 4-9 shows the distribution of risk by net infiltration rate in unweighted terms. Wetter climates are associated with higher release volumes and, consequently, greater risks. In the 0.25-inch setting, risk exceeds 10^{-6} in only 15 percent of the scenarios and never exceeds 10^{-5}. In the wettest setting (20-inches), risk falls into the 10^{-6} to 10^{-5} risk range in over 30 percent of the scenarios and is greater than 10^{-5} in over 42 percent of the scenarios. In the intervening net infiltration settings, risk increases with infiltration. The high-risk profile associated with the 20-inch infiltration region is mitigated by its relatively low frequency (about 12 percent). Over two-thirds of the landfills are split about equally between the 0.25- and 10-inch settings, which have the greatest effect on the overall risk distribution. Thus, because landfills are almost equally likely to be found in wet or arid climates, no one infiltration rate setting has a dominant influence on the overall risk distribution.

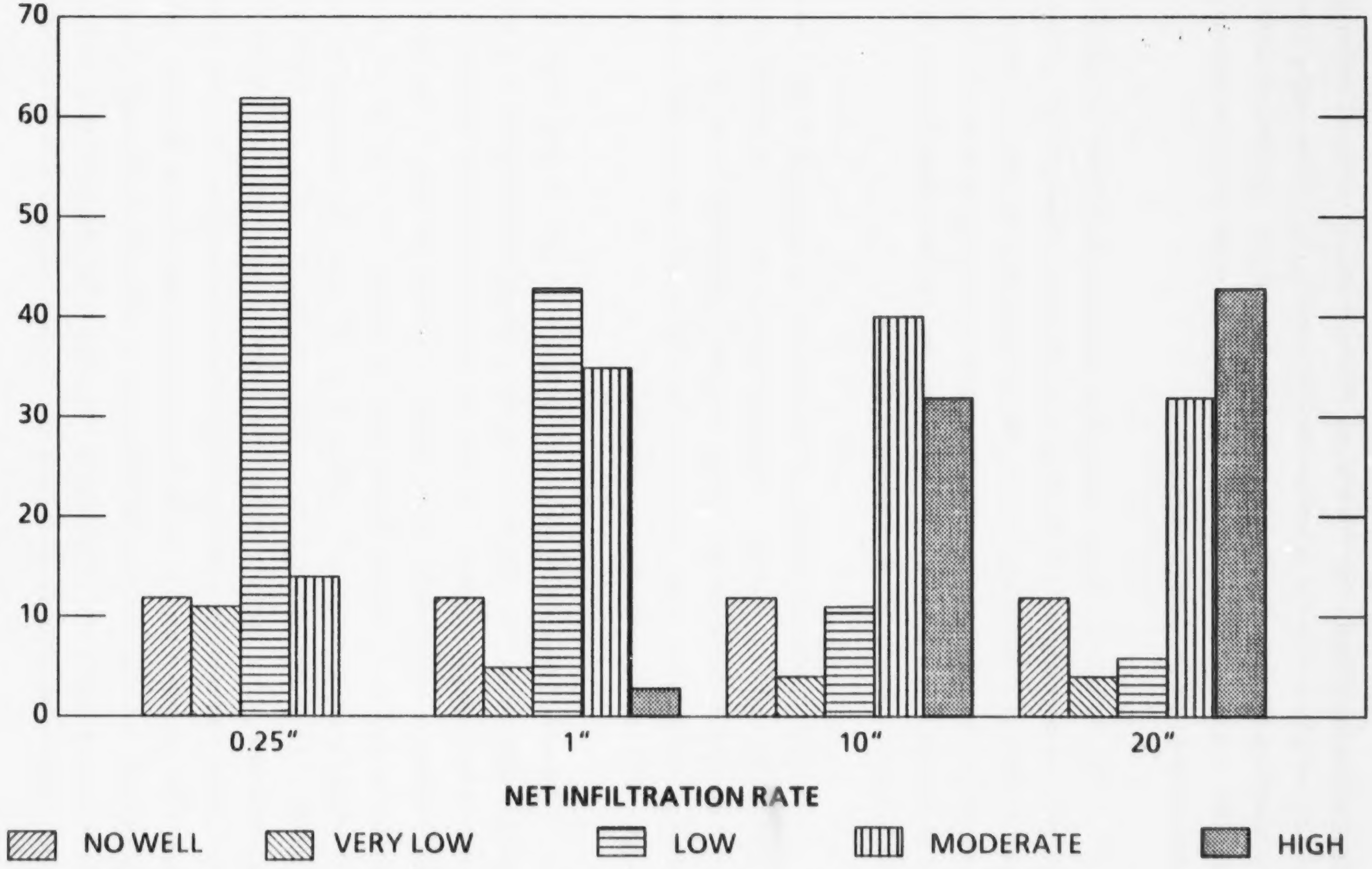
Hydrogeologic characteristics of the aquifer also exert a strong influence on risk. Aquifer properties affect the extent of dilution of the leachate and the retardation and degradation of specific pollutants. The EPA's results indicate that the slowest and fastest flow fields have lower risk profiles than the intermediate-velocity fields. Aquifers with slow velocities (i.e., 1 meter per year) generally allow for no pollutant breakthrough at the more distant wells and for considerable pollutant degradation before breakthrough at nearby wells. In the high-velocity flow fields (i.e., 1,000 and 10,000 meters per year), considerably more water flows through the aquifer, which affords more dilution of the leachate. Intermediate-velocity aquifers (i.e., 10 and 100 meters per year) have higher risk profiles because they neither allow for much degradation nor provide for much dilution or pollutant dispersion.

In summary, EPA estimates that about 17 percent of MSWLFs have risks that exceed 10^{-6} under the current well distribution. The model only estimates risks for facilities with drinking water wells within one mile. This percentage could increase if new wells were drilled in the vicinity of landfills or if new landfills were sited near existing wells. The risk analysis indicates that infiltration rate, facility size, distance from the facility, and aquifer characteristics are strong determinants of risk. However no single factor is responsible for most of the variation.

FIGURE 4-9

DISTRIBUTION OF AVERAGE RISK - BASELINE

BY NET INFILTRATION RATE (NORMALIZED)



Resource Damage Results--For this analysis, EPA has measured resource damage as the replacement cost (in present value terms) to provide drinking water to users whose supply is contaminated by releases from MSWLFs. Replacement costs for other uses (e.g., agricultural) were not addressed. In addition, as a second measure of resource damage, the model estimates the total area of contaminated ground water in the baseline.

The Subtitle D Risk Model calculates resource damage for both "use value" and "option value." Use value applies to all landfills that currently have downgradient drinking water wells within one mile of the facility boundary (46 percent of existing MSWLFs). Option value represents the replacement cost for ground water that does not currently serve as a drinking water source but may do so (at a given probability) in the future. Because the probability is low initially and increases with time, option value is always less than use value.

Another important point concerning the resource damage estimates is the impact of time and discounting. In the risk analysis, a cancer case is counted the same whether it occurs in the first year of the simulation or the last year. When considering the value of a resource, however, EPA has discounted future cash flows. As a result of this discounting, the timing of plume formation has a significant impact on the resource damage results.

Figure 4-10 presents the weighted distribution of resource damage for all units, expressed in present value terms. The numbers on the x-axis represent the upper bound of the resource damage interval (e.g., the bar labeled 0.4 includes landfills with replacement costs higher than $0.2 million but less than or equal to $0.4 million). The EPA estimates that resource damage ranges from $0 to more than $4 million and that the total resource damage for all 6,000 landfills is about $2.58 billion. The model predicts that about 31 percent of landfills have resource damage exceeding $200,000, and about 13 percent have resource damage in excess of $1 million. The model predicts that approximately 29 percent of the landfills will have no resource damage. Figure 4-10 also shows how the distribution of resource damage divides into use value and option value. Because option value is based on the probability that a ground-water source may someday be used, it tends to be much lower than use value for a given set of conditions. In fact, the model data indicate that option value is, on average, only a tenth of use value. The result is that option value dominates at lower levels of resource damage, while use value is the only measure to appear at levels exceeding $400,000.

Figure 4-11 summarizes the resource damage estimates in terms of a cumulative frequency distribution. This graph includes both use and option values. The median resource damage is about

FIGURE 4-10

DISTRIBUTION OF RESOURCE DAMAGE

BASELINE

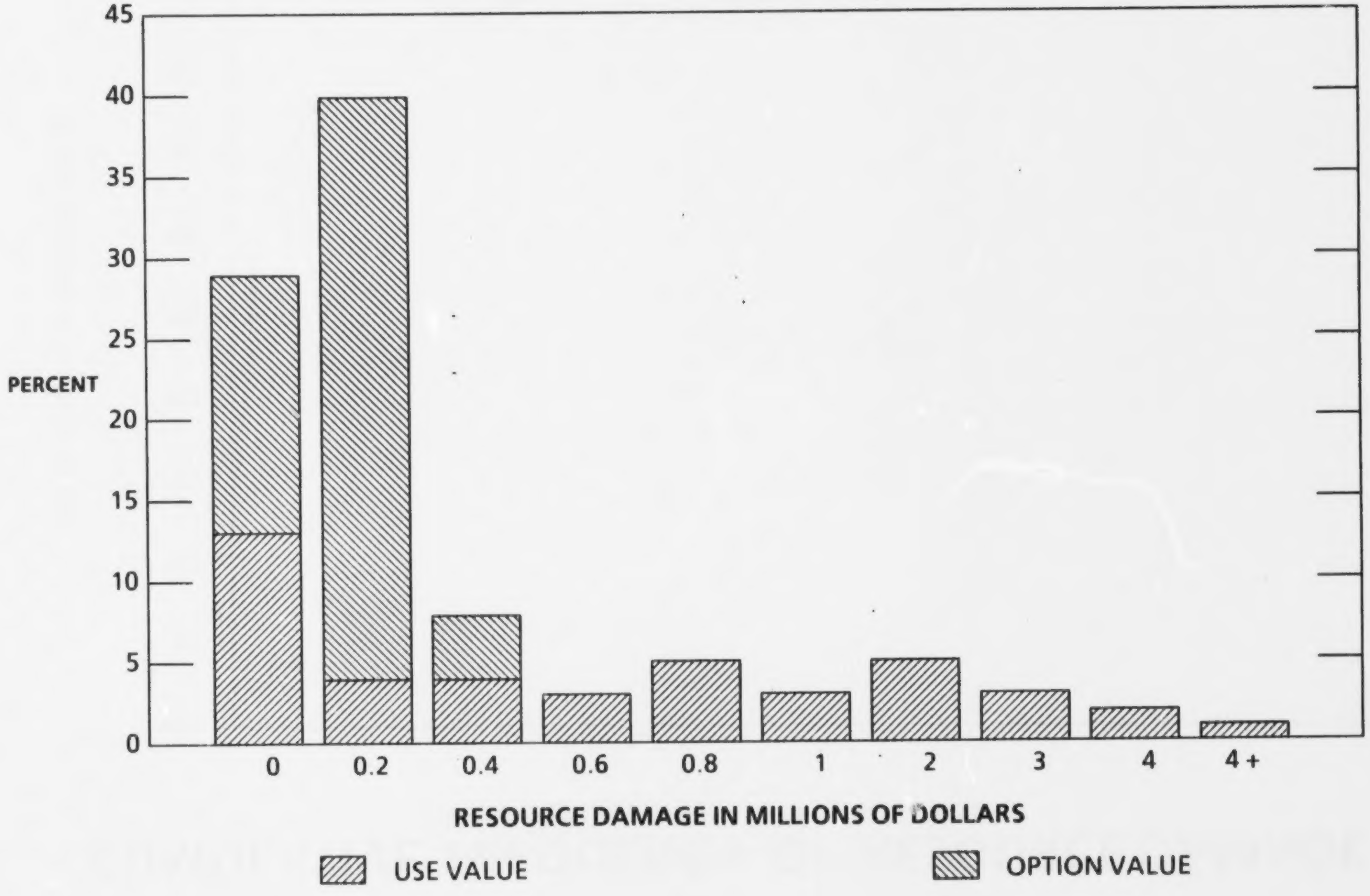
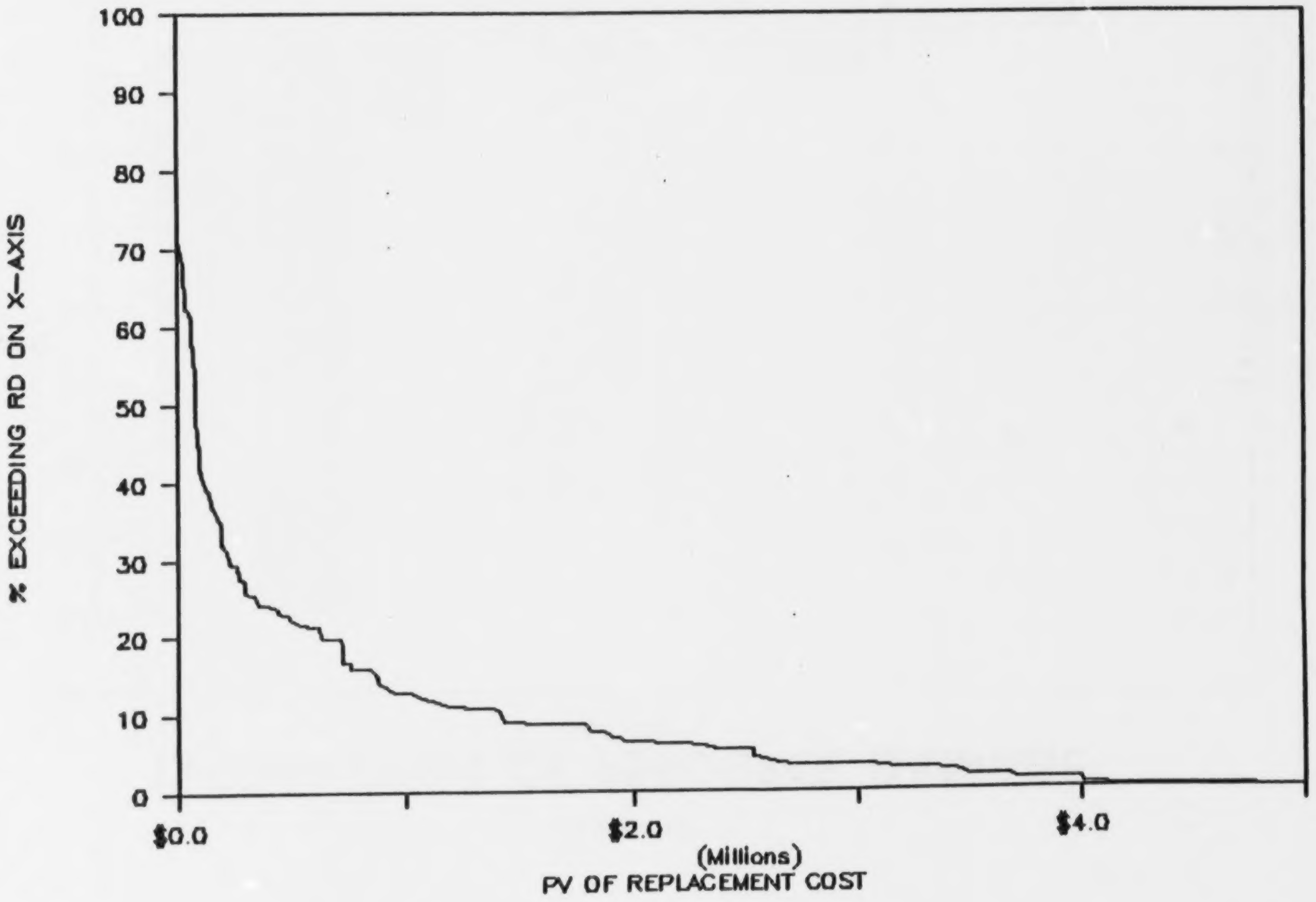


Figure 4-11

CUMULATIVE FREQUENCY OF RESOURCE DAMAGE

BASELINE: USE VALUE AND OPTION VALUE



$79,000. Thirteen percent of the landfills have damages exceeding $1 million, and 7 percent exceed $2 million. Figure 4-12 presents the cumulative frequency distribution for use value alone. The median replacement cost for this subset of landfills is about $485,000, and about 28 percent of these landfills have damages that exceed $1 million.

Similar to the risk results, resource damage estimates are strongly influenced by facility size and environmental setting. The following is a discussion on how these variables interact to affect the timing and size of plume releases from MSWLFs. Because use and option values are highly correlated, only the use value results are presented (those landfills with wells within one mile).

Figure 4-13 shows that landfill size has a large impact on resource damage. Slightly less than 30 percent of the 10-TPD scenarios have resource damage greater than $1 million. In sharp contrast, 66 percent of the 750-TPD MSWLFs have resource damage greater than $1 million, and nearly 30 percent of these landfills have damage in excess of $3 million. Less than 20 percent of the 750-TPD landfills have no resource damage. The greater mass of waste and larger area of these facilities lead to larger plumes and, as a direct result, higher resource damage. The high resource damage estimates at the large landfills are mitigated by their small proportion in the landfill population.

Net infiltration has a strong effect on resource damage, as shown in Figure 4-14. Infiltration affects both plume size and the timing of plume development. In wetter climates, plumes tend to be larger and to occur sooner because greater pollutant mass is released earlier in the modeling period. In the driest setting, 0.25-inch, most of the scenarios have no resource damage, and the number steadily decreases in the higher intervals. This pattern reverses in the 20-inch setting where a growing proportion of scenarios falls into the higher resource damage intervals. However, the higher resource damage levels from MSWLFs in the 20-inch setting (12 percent of all facilities), are mitigated by the lower levels from landfills in the 0.25- and 10-inch settings.

Aquifer characteristics also affect resource damage. In the aquifers of lowest velocity, plumes grow relatively slowly, but pollutant concentrations remain relatively high. In the aquifers of highest velocity, plumes grow rapidly but also dissipate rapidly. In the moderate-velocity flow fields, plumes grow rapidly and remain above threshold concentrations for a long period. Consequently, lower resource damages occur at either extreme, and higher resource damages occur in the middle-velocity flow fields. Thus, similar to the risk results, the slowest and fastest aquifers (1 meter per year, and 1,000-10,000 meters per year, respectively) have lower resource damage profiles than the moderate flow fields (10-100 meters per year).

Figure 4-12

CUMULATIVE FREQUENCY OF RESOURCE DAMAGE

BASELINE: USE VALUE ONLY

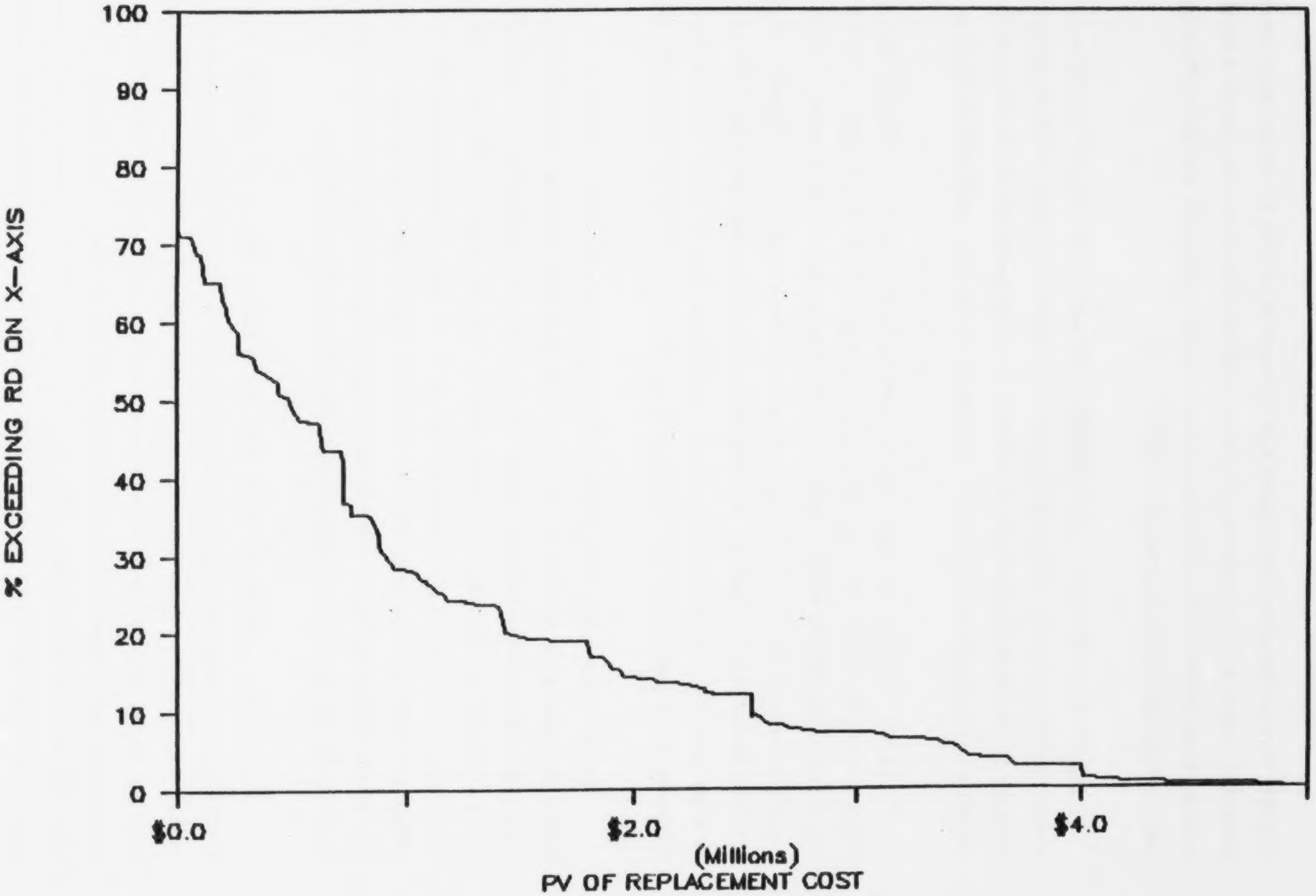


FIGURE 4-13

DISTRIBUTION OF RD - BASELINE

BY SIZE (NORMALIZED)

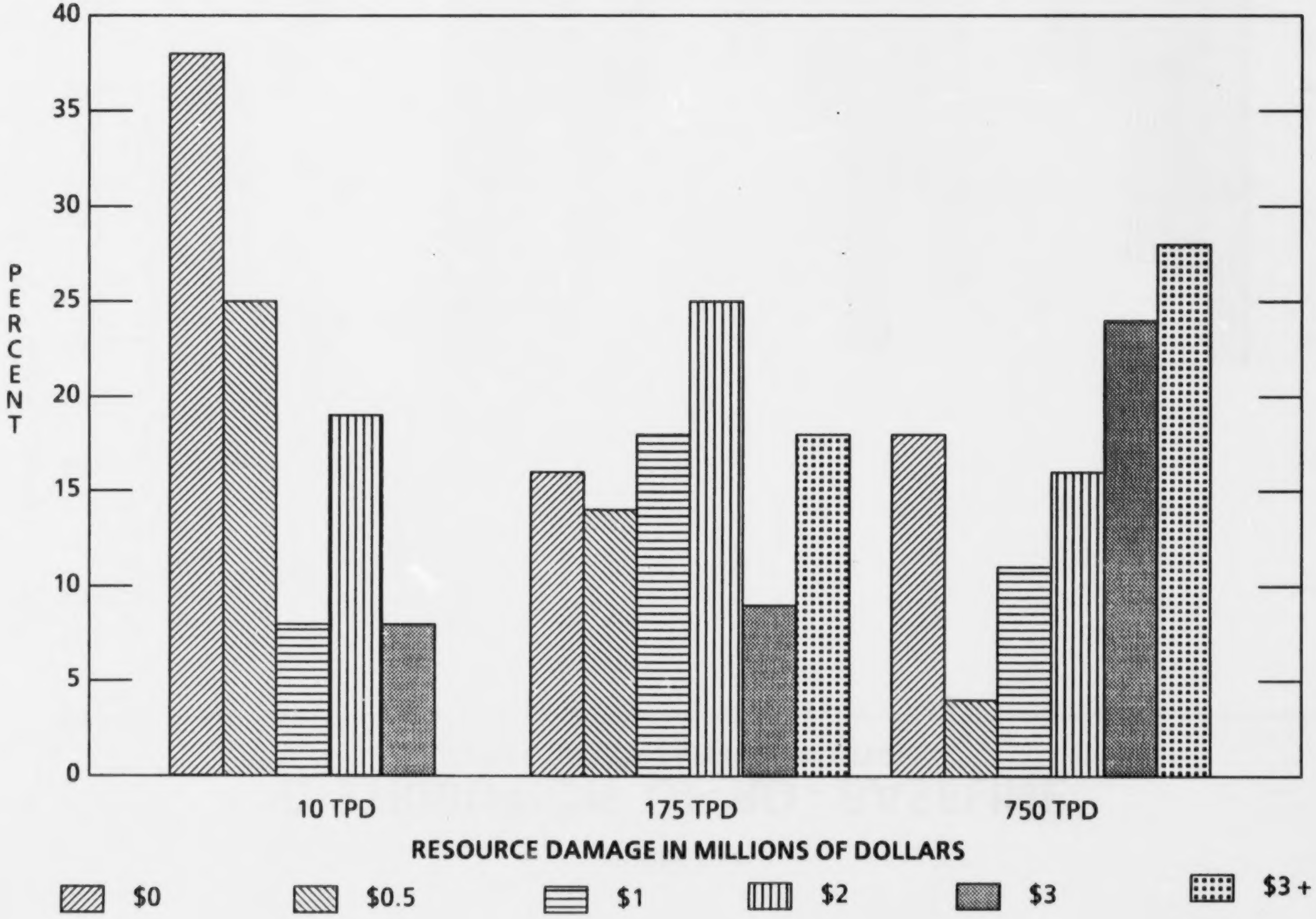
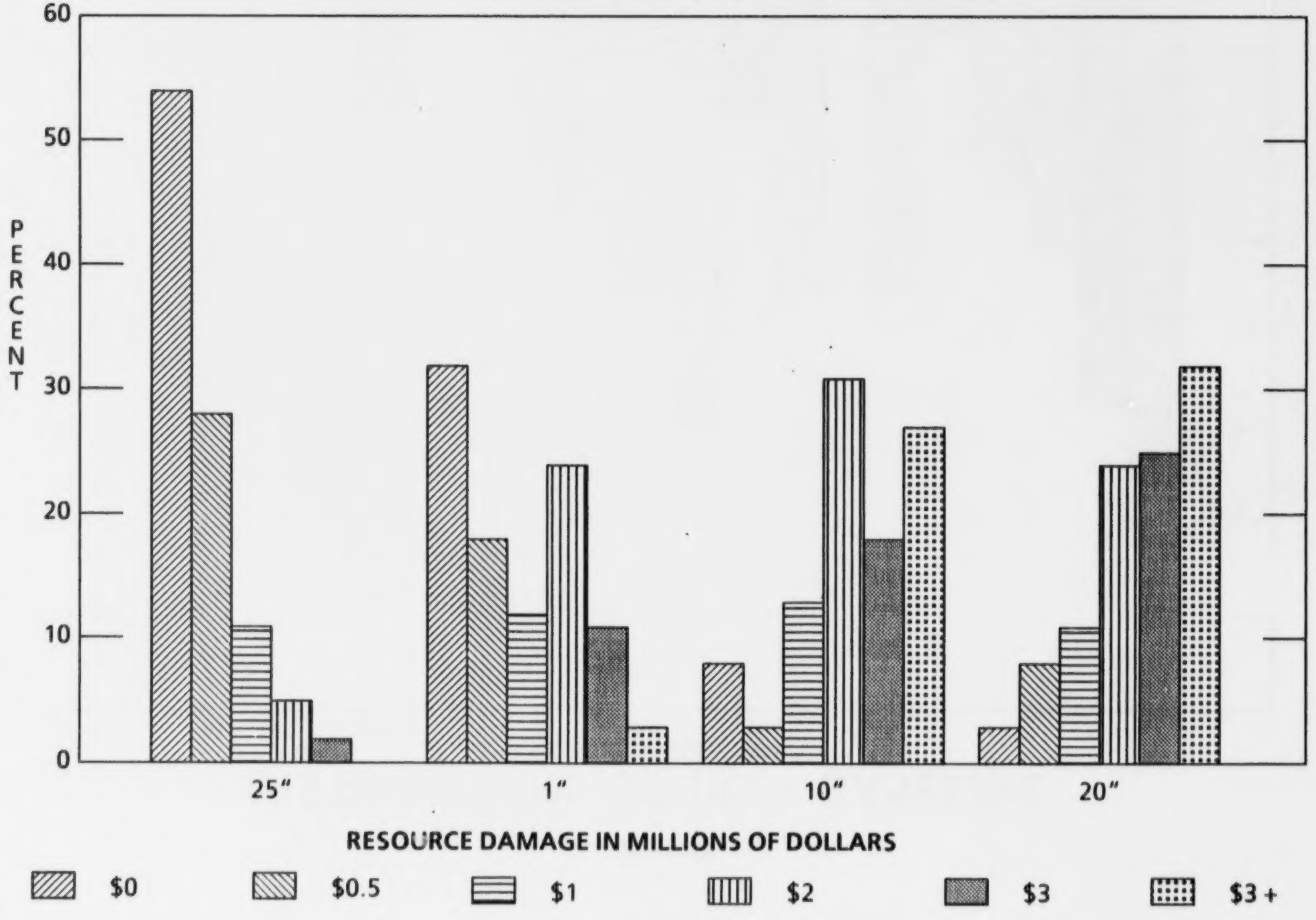


FIGURE 4-14

DISTRIBUTION OF RD - BASELINE

BY INFILTRATION RATE (NORMALIZED)



In summary, EPA estimates that 13 percent of all MSWLFs have resource damage in excess of $1 million, 31 percent have levels exceeding $200,000, and 29 percent of all MSWLFs will have no resource damage. The low present value estimates for some facilities are due to the fact that ground water is not currently used at 54 percent of all landfills. In some situations, however, resource damage can be more than $4 million. Estimates of resource damage are heavily dependent on the current status of ground-water use, plume size, and the timing of contamination.

National Priorities List/Subtitle D Data

The report on National Priorities List/Subtitle D landfills[32] identified some pertinent characteristics of the Subtitle D landfills on the National Priorities List (NPL) (as of May 1986). Of the approximately 19,000 sites inventoried by EPA as hazardous waste substance sites and listed on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) data base (CERCLIS), approximately 2,000 were identified as Subtitle D landfills by EPA. Of the sites ranked by EPA as part of the process of identifying sites for inclusion on the NPL, 325 were identified as Subtitle D landfills that have received municipal wastes. Finally, of the 850 sites listed or proposed for listing on the NPL, 184 were identified as NPL/Subtitle D landfills that had received municipal wastes. This relationship is illustrated in Figure 4-15.

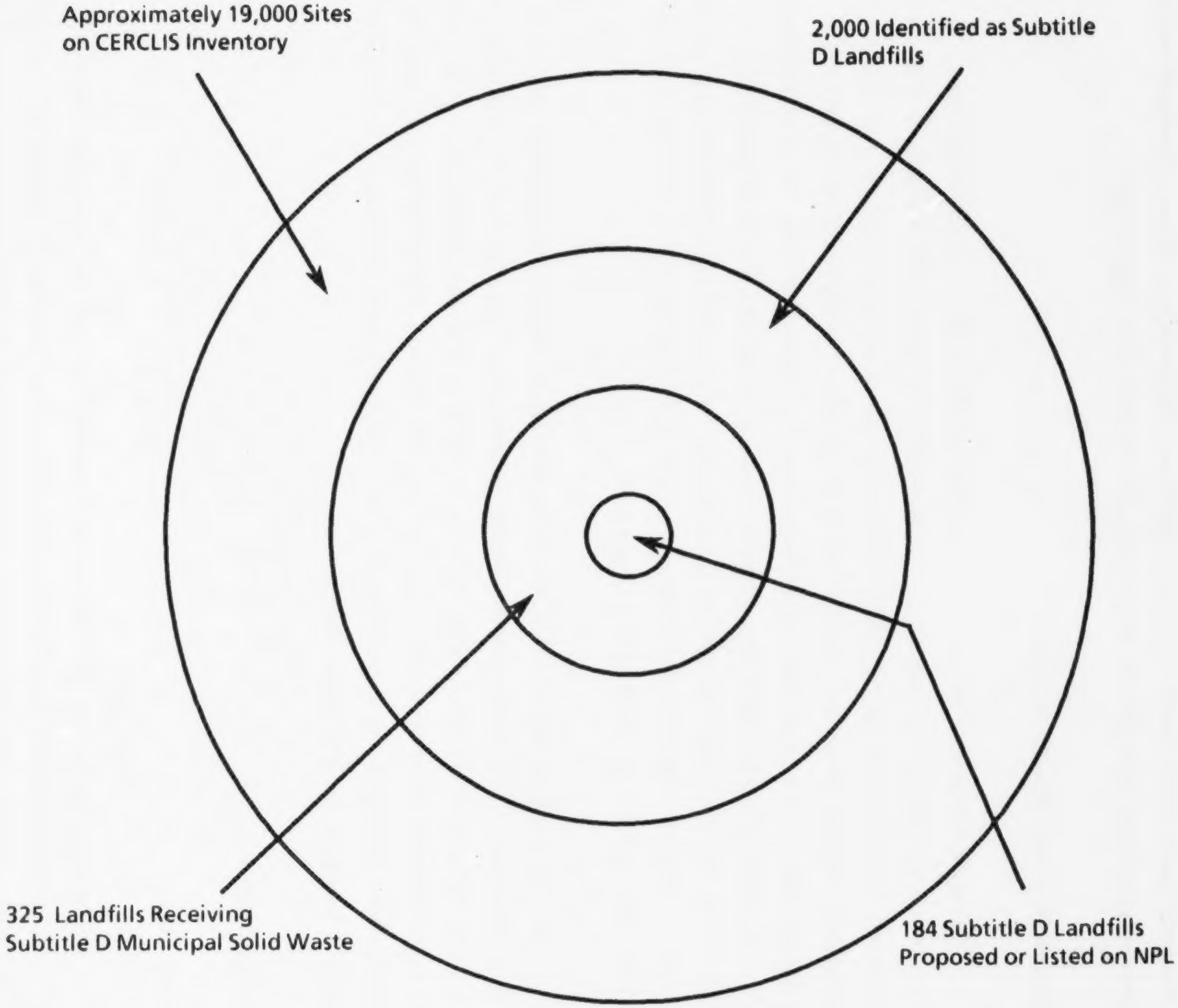
The most common chemicals found at these landfills are halogenated organics, aromatics, and metals. No specific chemicals were cited as being most common. The most significant chemical origin was found to be industrial waste, followed by sludge and household hazardous waste. The NPL sites have been scored using the Hazard Ranking System (HRS). The system considers the toxicity of substances, observed or potential releases to the surrounding media, and the potential routes of exposure, as well as the population exposed.

Surface Water

Census Data

The census indicates that 660 MSWLFs were contaminating surface water, compared to 50 industrial landfills, 42 demolition debris landfills, and six other landfills (see Table 4-50). The higher incidence of violations at municipal landfills is most likely due to a higher incidence of monitoring and State inspections at those landfills. Surface water violations were detected from facility monitoring data or from samples taken during inspections. For reasons cited previously, the number of reported violations is an imperfect measure of environmental impacts.

Figure 4-15. SUBSET OF SUBTITLE D LANDFILLS WITHIN CERCLIS DATA BASE


Approximately 19,000 Sites on CERCLIS Inventory
2,000 Identified as Subtitle D Landfills
325 Landfills Receiving Subtitle D Municipal Solid Waste
184 Subtitle D Landfills Proposed or Listed on NPL

SOURCE: Reference 30.

Case Studies

At 73 of the 163 MSWLF case studies,[30] there was documentation or evidence of surface water degradation as a result of leachate seeps, run-off control deficiencies, or locating in a wetland or floodplain. While the extent of surface water degradation was limited in most cases, some impacts had either an effect on local wetland environments or subsequently caused ground-water degradation.

A few examples of ecological damage was also identified. Impacts on fish or other aquatic life have been documented at 13 sites. However, ecological damages associated with MSWLFs are difficult to identify and often not investigated; therefore, this small number of cases does not likely reflect the actual number of occurrences. Acute catastrophic impacts (e.g., a major fish kill) are not usually associated with MSWLFs. Municipal solid waste landfills are more likely to discharge contaminants to surface water, causing subtle changes to the aquatic environment. For example, in one of the 13 damage cases mentioned above, a five-year study was conducted that was specifically designed to determine what impacts a landfill had on benthic (bottom) organisms in a nearby stream. The results indicated that the diversity of benthic organisms downstream was much less than that found upstream. The few species that survived downstream were more tolerant of the higher metal concentrations present as a result of the landfill. These subtle changes would not have been identified during normal inspections. EPA concludes from this that there are probably more cases of ecological damage from MSWLFs than the Agency has documented.

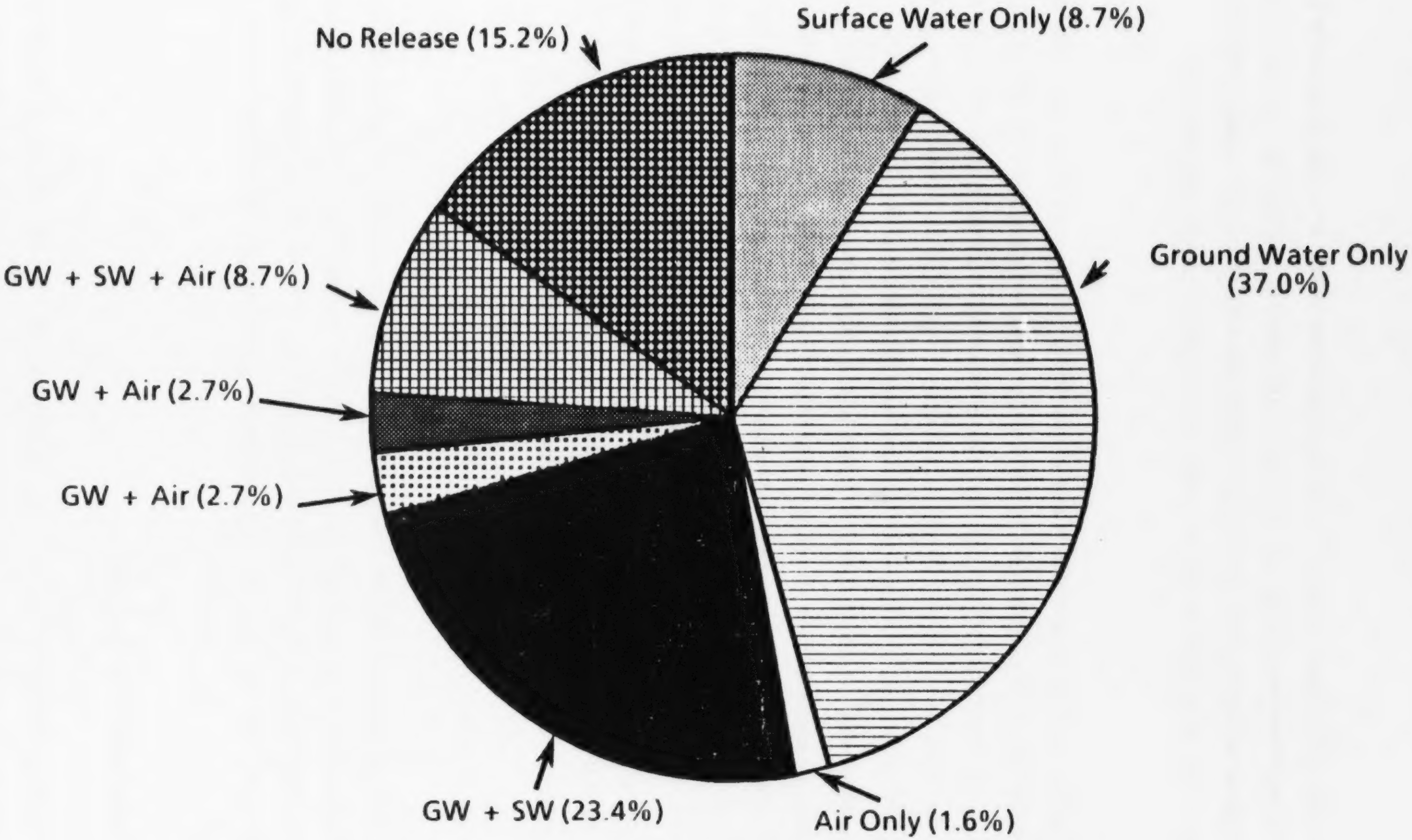
National Priorities List/Subtitle D Data

Of the 184 Subtitle D landfills either listed on the NPL or being considered for listing, surface water was found to be affected at 43 percent of these sites (see Figure 4-16). Liquid waste was present at approximately 70 of the facilities showing surface water contamination, while sludge was present at approximately 45 sites. Pesticides were found to be present at only approximately ten of those sites affected.

Municipal Solid Waste Landfill Survey Data

The MSWLF Survey estimates that less than 1.5 percent of the landfills are located within one mile of a surface water body used for drinking. Only 66 landfills are located near surface water bodies that serve more than 100 people.

Figure 4-16. OBSERVED RELEASES AT SUBTITLE D LANDFILLS ON THE NPL



OF THE 850 SITES LISTED OR PROPOSED FOR LISTING ON THE NPL,
184 SITES ARE SUBTITLE D LANDFILLS.

SOURCE: Reference 32.

The MSWLF Survey also provided data on the distance from each landfill to the nearest surface water body not used for drinking. Table 4-52 presents the distribution of MSWLFs according to the distance to the nearest surface water body not used for drinking. The table presents data for rivers/streams, lakes/reservoirs, and wetlands and indicates that approximately 40 percent of all MSWLFs are located within 1/4 mile of a surface water body.

Table 4-52. NUMBER OF MUNICIPAL SOLID WASTE LANDFILLS BY DISTANCE TO NEAREST SURFACE WATER BODY NOT USED FOR DRINKING

Distance to Nearest Surface Water Body	Type of Surface Water Body		
	Rivers/Streams	Lakes/Reservoirs	Wetlands
Distance Unknown	73	52	61
0 Miles	57	7	70
Less than 1/4 Mile	1,574	268	600
1/4 - 1/2 Mile	580	156	128
1/2 - 1 Mile	655	187	117
Total	2,939	670	976

SOURCE: Reference 3.

Air

Census Data

As shown in Table 4-50, the Subtitle D census provides information on the number of facilities that have air monitoring, and information on air quality violations that have been reported to occur in 1984. These data indicate that 845 MSWLFs were contaminating the air, compared to 18 industrial landfills, 33 demolition debris landfills, and 54 other landfills. These groups reported 180, eight, zero, and one incidences of deficient methane controls, respectively. More MSWLFs conduct air monitoring than do other types of Subtitle D landfills. This may account for the larger number of violations at MSWLFs. Air contamination and methane control deficiencies may be detected from facility monitoring data or sampling during State inspections. For reasons cited previously, the number of reported violations is an imperfect measure of environmental impacts.

Twenty-nine landfill gas migration damage cases were identified for another report to Congress now being prepared by EPA on extending the useful life of MSWLFs (see Table 4-53).[19]

Table 4-53. LANDFILL GAS MIGRATION DAMAGE CASES

Landfill, Location, and Date of Event	Methane Detected Off-Site Above LEL?/Distance[a]	Explosion/Fire?	Landfill Characteristics and Corrective Action[b]	Damages and Other Comments
Fresno, CA April 1984	Yes/N/A	Yes On-Site	Control system installed after incident.	Fresno police bomb squad used site for practice. A bomb was buried and was detonated causing LFG explosion. Explosive levels of methane were migrating off-site.
Monterey Park, CA August 1983	Yes/No information available.	No	Class 1 landfill LFG recovery system present. Control system existed prior to incident.	Vinyl chloride detection caused SCAQMD to order 30-day shutdown of landfill. It reopened, subject to closure in six months.
West Covina, CA August-October 1984	Yes/250	Yes	Class 1 landfill. Control System expanded after incident.	Twenty residences temporarily evacuated due to explosive methane levels in adjoining soils.
Topeka, KA August 1983	Yes/No information available.	No	No information available.	Home abandoned due to high methane levels.
Cincinnati, OH 1983	Yes/300	Yes[c] Off-Site	No liner present. Control system installed after the incident.	Explosion destroyed residence across the street from the landfill. Minor injuries reported.
Wallingford, CT June 1984	Yes/No information available.	No	LFG recovery system present.	Explosive levels of methane detected in dog pound. Dog pound temporarily closed, ventilation system to be installed.
Cleveland, OH 1980	Yes/100	Yes[c] Off-Site	No liner present: Soils consist of silt and clay. Control system installed after the incident.	Explosion killed foundry worker on site adjacent to landfill.

Table 4-53. (Continued)

Landfill, Location, and Date of Event	Methane Detected Off-Site Above LEL?/Distance[a]	Explosion/Fire?	Landfill Characteristics and Corrective Action[b]	Damages and Other Comments
Richmond, VA 1975	Yes/20	Yes Off-Site	No liner present.	In 1975, explosion occurred in nearby apartment building. The City decided to buy and demolish it. Two schools sited on the landfill were closed until a control system was installed.
Richmond, VA 1982	No/N/A	Yes[c] On-Site	No information available.	The 1982 incident occurred when children trespassed onto the landfill site, entered a control system manhold, and lit a match, resulting in an explosion. The nature of the associated injuries has not been disclosed. The case is in litigation.
Manchester, NJ December 1983	No/N/A	Yes On-Site	Ventilation and alarm systems to be installed in the remaining maintenance garage.	Spark from landfill pump probably ignited methane gas, causing explosion and fire. One person sustained first and second degree and flash burns. Office building destroyed.
Wanaque, NJ March 1984	No information available.	Yes	Control system proposed for school located on a closed landfill.	No information available.
Comack, NJ May 1984	Yes/50	Yes[c] On-Site	No liner present. Sandy soils. Control system installed after incident.	Methane migrated to the scale-house on-site. Explosion killed one person and injured another.

Table 4-53. (Continued)

Landfill, Location, and Date of Event	Methane Detected Off-Site Above LEL?/Distance[a]	Explosion/Fire?	Landfill Characteristics and Corrective Action[b]	Damages and Other Comments
Baltimore, MD April 1983	Yes/No information available.	No	Solid waste with illegally-dumped hazardous waste. Soil type is clay with sand lenses. Native clay serves as a liner.	Vent pipes were not maintained, causing vents to become non-functional. Street light fire was believed related to methane migration. Ongoing lawsuit concerns presence of priority pollutants.
Jersey City, NJ 1984	No/N/A	Yes On-Site	Solid waste with illegally-dumped hazardous waste. An NPL site.	Landfill fires causing air pollution have been a problem for years.
Oceanside, CA 1981	Yes	No	No liner present. Control system installed after the incident.	Schools surrounding the landfill were evacuated and classes were suspended for 4-5 months.
Adams County, CO 1977	Yes	Yes[c] Off-Site	No information available.	Explosion caused two fatalities and injured seven others at a pipeline construction project adjacent to the landfill.
Springfield, IL 1979	Yes/200	Yes[c] Off-Site	No liner present. Control system installed after the incident.	Methane migrated into construction company offices adjacent to the landfill. Limited fires occurred. No explosion. Building evacuated and use restricted for four weeks.
Louisville, KY 1978	Yes/200	No	No liner present. Soils are sandy with clay and silt layers interspersed. Control system installed after the incident.	No physical damages occurred. Buildings evacuated for short period of time.

Table 4-53. (Continued)

Landfill, Location, and Date of Event	Methane Detected Off-Site Above LEL?/Distance[a]	Explosion/Fire?	Landfill Characteristics and Corrective Action[b]	Damages and Other Comments
Louisville, KY 1978	Yes/1,000	Yes[c] Off-Site	No liner present. Soils are clayey silt to gravelly sand. Control system installed after the incident.	Small fires and explosions. Several houses evacuated and condemned. Benzene (29.5 ppm) and vinyl chloride (17.9-122.6 ppm) detected off-site.
Frostburg, MD 1978	Yes/200	Yes[c] Off-Site	No liner present. Soils are silt and clay. Control system installed after the incident.	Limited fire in off-site equipment maintenance building. No explosion. Building use restricted for two months. Building was highly ventilated until gas control system installation.
Rockville, MD 1980	No/N/A	Yes[c] Off-Site	Old, inactive dump site. Building constructed on inactive disposal site. Control system installed after the incident.	Small explosion occurred in enclosed back room of auto body shop. A janitor was injured. Shop closed for one month until control system was installed.
Winston Salem, NC 1969	Yes/100	Yes[c] Off-Site	Codisposal. No liner present. Control system installed after the incident.	Methane migrated into National Guard Armory. Explosion killed three guardsmen, seriously injured twelve, and twenty-five other guardsmen experienced less serious injuries. Seven of the injured have become partially or completely disabled.
North Hempstead, NY 1981	Yes/200	Yes[c] Off-Site	Liner present. Soils sandy with some clay and silt layers.	Small explosion in furnace rooms of several homes. Minor damage occurred. Furnaces were replaced.
Smithtown, NY 1984	Yes/200	Yes[c] Off-Site	Liner is present. Soils are sandy.	Explosion damaged room in transfer station.

Table 4-53. (Continued)

Landfill, Location, and Date of Event	Methane Detected Off-Site Above LEL?/Distance[a]	Explosion/Fire?	Landfill Characteristics and Corrective Action[b]	Damages and Other Comments
Akron, OH 1984	Yes 500-1,000	Yes[c] On-Site	No liner present. Control system installed after incident.	One house destroyed. Ten houses evacuated temporarily. Several minor injuries.
Canton, OH 1984	Yes/No information available	No	No information available.	Two homes and a day care center temporarily evacuated.
Tyler, TX May 1982	No/N/A	No	Control system existed prior to incident.	TDPS office building sited on closed landfill. Methane has caused problems since early 1970's. Failure of ventilation exhaust fan resulted in "significantly high" levels of methane in the building.
Lorton, VA 1984	Yes 300-1,000	Yes[c] Off-Site	No liner present. Soils range from clay to sandy clay to sand. Control system installed after the incident.	One man was fatally injured and another burned over 50% of his body during explosion and limited fire.
Madison, WI	Yes 100-150	Yes[c] Off-Site	Soils are composed of clay, glacial fill, sand, weathered and fractured bedrock.	Explosion blew out one sidewall of a townhouse. Three adjacent apartment buildings and several homes evacuated for 20-30 days. Two people seriously injured. Claims filed against the City total $5.2 million.

SOURCE: Reference 19.

Symbols

N/A	Not Applicable.
a	Reported distance (in feet) of maximum migration, or distance to affected structure.
b	Landfills are municipal solid waste landfills (publicly or privately owned/operated) unless otherwise noted.
c	Personal injuries sustained and/or death occurred

Twenty-one of the 29 cases involved an explosion or fire, and 15 of those cases resulted in personal injuries and five involved fatalities. More than half of the landfills did not have a methane control system at the time of the incident.

Significant air pollution has resulted from methane gas-recovery operations at MSWLFs. Methane gas is produced in landfills during anaerobic bacterial digestion of organic matter. Gas that is produced in the landfill migrates through the refuse and soil by both convection and diffusion. Trace quantities of many other types of hazardous wastes have also been observed at Subtitle D landfills. Studies performed jointly and separately by the Gas Research Institute, the U.S. Department of Energy, and EPA[33,34] found that since methane gas is produced at most landfills, it may serve as a vehicle for other hazardous contaminants to be released to the atmosphere. In addition, landfill gas burned for energy recovery might expose consumers to hazardous contaminants found in the gas.

NPL/Subtitle D Data

The NPL/Subtitle D Landfill Study showed that only 16 percent of the 184 NPL/Subtitle D landfills had significant air emission problems (see Figure 4-16). Most of these sites were used primarily for industrial waste disposal.

Indian Reservation Surveys

EPA recently sponsored a survey of 48 Indian reservations.[35] Forty-four (44) percent of the reservations cited solid waste disposal as a major problem. Fifty (50) percent of the reservations surveyed reported that "community dumps" were used for disposal. Roadside dumps and other unauthorized open dumps were reported by nearly 20 percent of the reservations. Open burning and community dumps were cited several times as a source of air pollution. Landfill leachate was cited six times as the actual source of water pollution and 24 times as a potential source.

A survey of the eleven Tribes of the Great Lakes Indian Fish and Wildlife Commission was also conducted.[36] The Tribes were asked to prioritize environmental concerns. The second most important concern, after surface water quality, dealt with solid waste control. Seven Tribes (63 percent) cited unauthorized landfilling as a problem. Other problems reported included unauthorized burning and lack of capacity. Two of the Tribes cited landfills as the source of surface water pollution. A third survey of potential hazardous waste sites in EPA's Region 5 found 66 open dumps on 29 Indian reservations.[37]

In addition to these surveys, other informal communications with various Tribes indicate that solid waste disposal is an important environmental issue on reservations. Current data, however, are extremely limited. More information is necessary to determine whether human health and/or the environment are being threatened.

4.2 SURFACE IMPOUNDMENTS

This part presents a general profile of Subtitle D surface impoundments (SIs). It also discusses SI design and operation, and environmental and human health impacts at SIs.

4.2.1 GENERAL PROFILE

The Subtitle D census provided general information on SIs, including numbers, ownership, acreage, and waste volumes. Information on waste characteristics was available through other sources. The Subtitle D census defined SI as:

> A part of an establishment which is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials (although it may be lined with man-made materials) that is designed to hold an accumulation of liquid wastes or wastes containing free liquids. Treatment, storage, and disposal SIs are included. SIs are often referred to as pits, ponds, or lagoons. This definition does not include any type of tank, including concrete, fiberglass, or steel tanks.

This definition is broken down further into the following categories:

Municipal sewage sludge surface impoundments receive sewage sludge from publicly owned or privately owned domestic sewage treatment establishments, including septic tanks.

Municipal run-off surface impoundments are used for the collection of run-off or leachate from MSWLFs or municipal solid waste land application units.

Industrial waste surface impoundments receive wastes primarily from factories, processing plants (including food processing), and other manufacturing or commercial activities. Also included in this category are SIs used for the collection of run-off or leachate from industrial or demolition landfills and industrial land application units.

Agricultural waste surface impoundments receive waste only from agricultural operations, including farming, crop production, and animal husbandry (including feedlots). Specifically excluded from this category are SIs used for waste from slaughterhouses and other animal and food processing operations, which are included in the industrial SI category.

Mining waste surface impoundments are associated with mineral extraction and beneficiation activities, such as crushing, screening, wasting, and flotation. These minerals include metallic and nonmetallic ores, coal, sand, and gravel. They exclude oil and gas processing wastes from manufacturing establishments, which are included in the industrial SI category.

Oil or gas surface impoundments receive waste from oil and gas exploration and extraction, commonly known as brine pits. Both disposal and emergency brine pits are included. Specifically excluded are SIs used for petroleum refinery wastes, which are included in the industrial SI category.

Other surface impoundments receive Subtitle D wastes, but do not fall into any of the above categories.

Number of Surface Impoundments

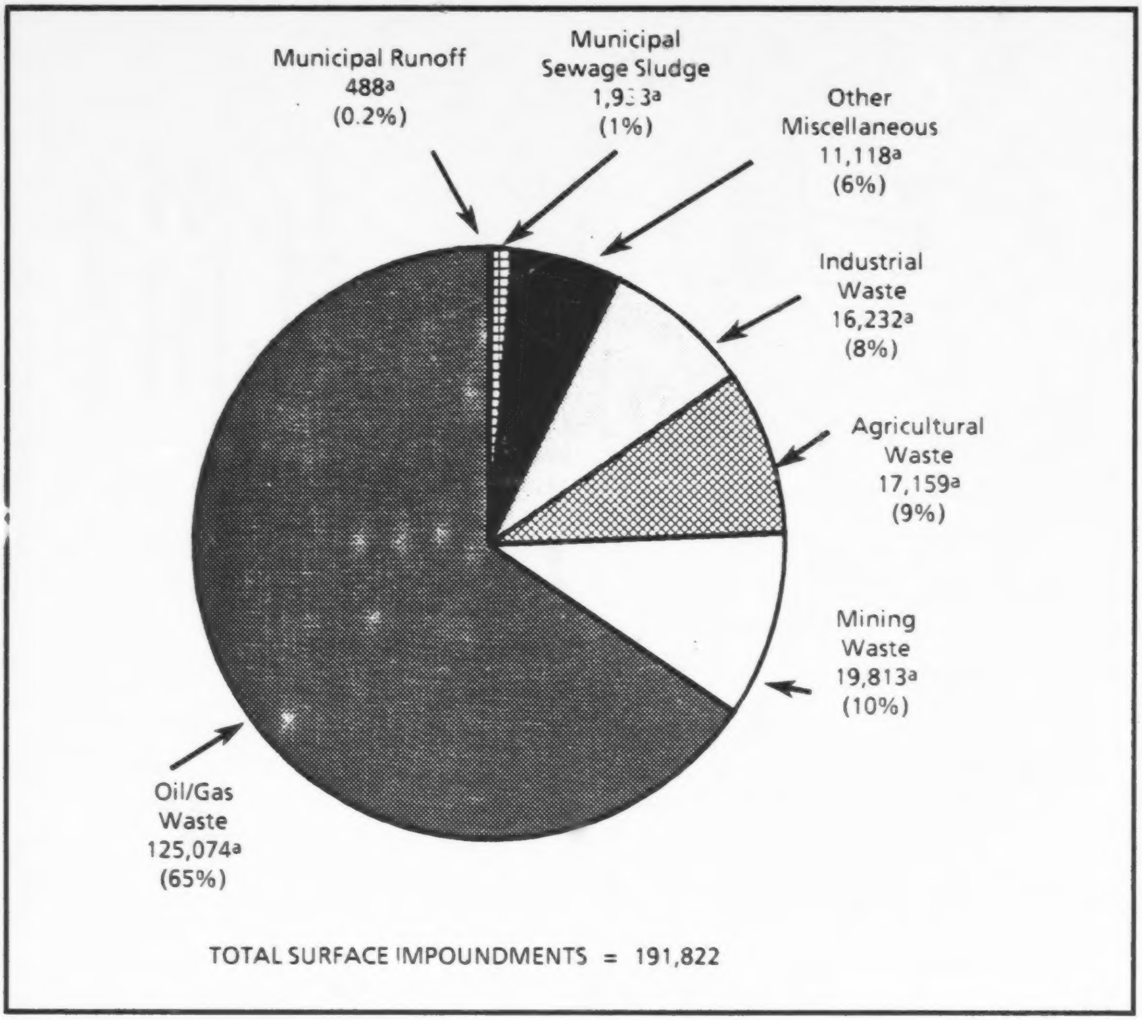
The Subtitle D census indicates that there were 191,822 active SIs in 1984 located at 108,383 establishments. There were more than five times as many oil or gas waste impoundments (125,074) as the next largest category, mining waste impoundments (19,813). Figure 4-17 depicts the numbers and relative shares of the seven different types of SIs. These impoundments are distributed throughout the country, as shown on the map presented in Figure 4-18. Pennsylvania reported the largest number of SIs (32,653), followed by Arkansas (25,705), Louisiana (20,010), West Virginia (18,705), and New Mexico (17,044).

The estimated number of Subtitle D SIs is believed to underestimate the actual number of SIs nationwide, owing to data gaps in the Subtitle D census. Nine States and territories were unable to provide any estimates for numbers of SIs. One State provided an estimate of the total, but was unable to break down that estimate into the different categories. Five more States could not provide estimates for one or more of the categories.

The SI Assessment National Report[38] provides a breakdown of numbers of agricultural and mining waste SIs, as illustrated in Table 4-54. The SI Assessment National Report was discussed in Chapter 2.

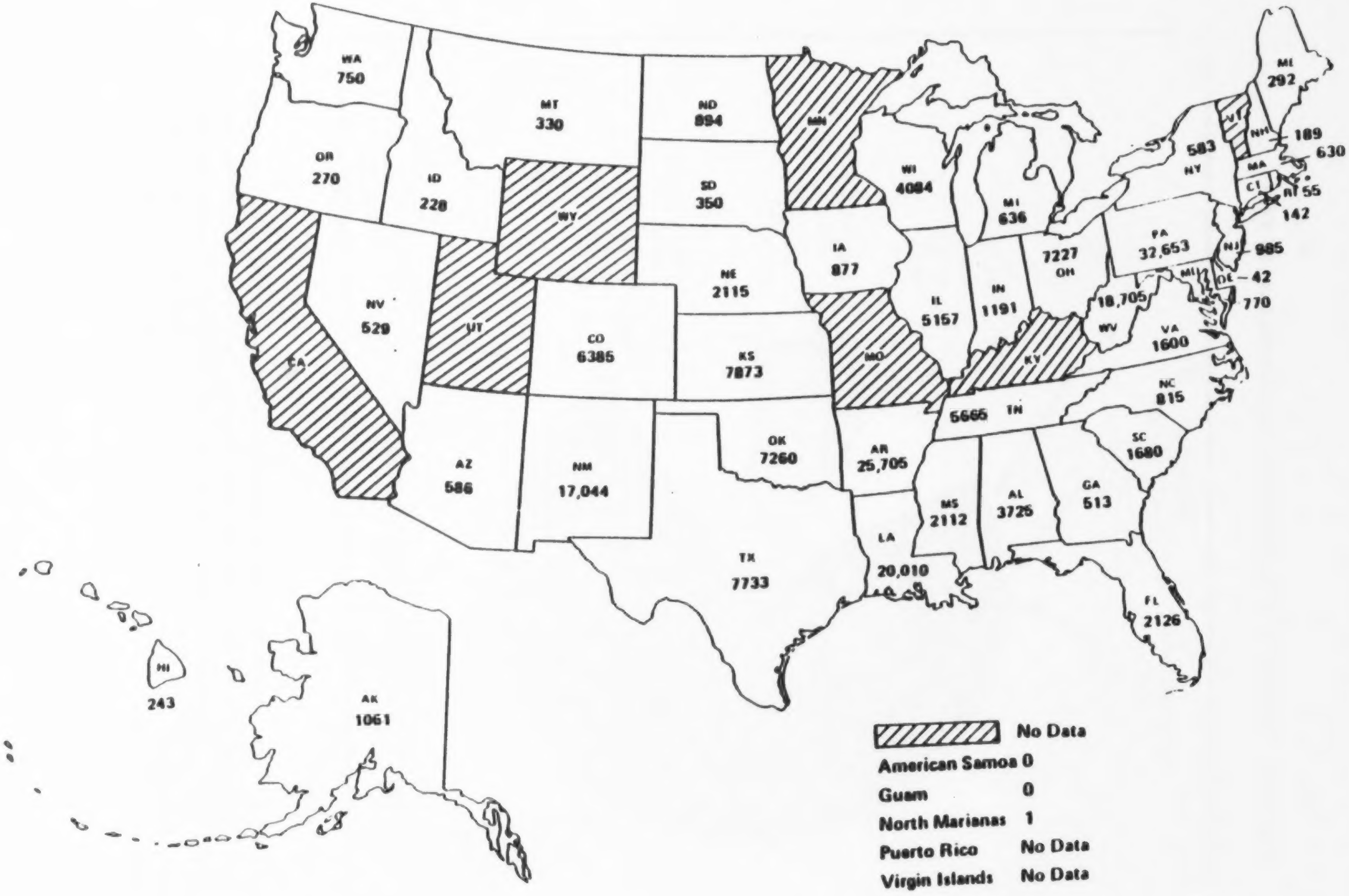
Table 4-55 presents results from the Industrial Facilities Survey on the numbers of Subtitle D SIs for seventeen major industries. The survey indicates that there are approximately 15,000 industrial

Figure 4-17. NUMBER OF ACTIVE SUBTITLE D IMPOUNDMENTS BY TYPE



SOURCE: Reference 1.

[a] No estimates of surface impoundments were obtained from CA, KY, MO, MN, UT, VT, WY, PR, and VI; estimate from SD was not broken down by category. In addition, no estimates of municipal sewage sludge were obtained from IL, LA, or RI; no estimate of industrial waste from LA; no estimates of agricultural waste from LA or NY; no estimate of mining waste from NY; no estimates of oil/gas waste from IN, MT, NY, or RI; and no estimates of municipal run-off from IL, LA, or RI.



American Samoa	0
Guam	0
North Marianas	1
Puerto Rico	No Data
Virgin Islands	No Data

SOURCE: Reference 1.

Figure 4-18 NUMBER OF SUBTITLE D SURFACE IMPOUNDMENTS BY STATE

Table 4-54. ESTIMATES OF SPECIFIC SUBTITLE D SURFACE IMPOUNDMENT NUMBERS AND WASTES RECEIVED WITHIN EACH IMPOUNDMENT CATEGORY

Waste Description	Number of Impoundments[a]
Agricultural Waste	17,159[b]
Livestock, general	5,333
Dairy farm	4,732
Hogs	3,492
Cattle feedlot	2,974
General farm	1,208
Poultry farm	717
Other fur-bearing animals	336
Crop production	190
Fish hatcheries	95
Mining Waste	19,813[b]
Bituminous coal and lignite	19,891
Nonmetallic minerals	2,272
Metals	1,754
Anthracite	459

SOURCE: References 1 and 38.

[a] Based on data from Reference 38 unless indicated otherwise. Note that numbers from various sources do not generally concur.

[b] Based on data from Reference 1. Note that numbers from various sources do not generally concur.

Table 4-55. NUMBER OF INDUSTRIAL ESTABLISHMENTS WITH SUBTITLE D SURFACE IMPOUNDMENTS AND NUMBER OF SURFACE IMPOUNDMENTS BY INDUSTRY TYPE

Industry Type	Total Number of Active Subtitle D Units[a]	Number of Active Surface Impoundment Units	Number of Establishments with Active Surface Impoundments	Number of Establishments with Closed Surface Impoundments
Organic Chemicals	385	262	88	41
Primary Iron and Steel	1,124	383	185	107
Fertilizer and Agricultural Chemicals	515	274	113	25
Electric Power Generation	1,528	1,220	322	40
Plastics and Resins Manufacturing	373	292	80	43
Inorganic Chemicals	1,281	1,039	345	173
Stone, Clay, Glass, and Concrete	7,247	3,152	1,977	315
Pulp and Paper	1,548	918	302	111
Primary Nonferrous Metals	880	448	188	136
Food and Kindred Products	8,029	4,166	1,713	406
Water Treatment	974	659	330	11
Petroleum Refining	1,249	915	321	108
Rubber and Miscellaneous Products	392	176	126	111
Transportation Equipment	723	287	121	101
Selected Chemicals and Allied Products	298	219	53	46
Textile Manufacturing	944	741	388	112
Leather and Leather Products	164	102	27	23
Total[b]	27,654	15,253	6,681	1,905

SOURCE: Reference 2.

[a] These numbers correspond to the total universe of active Subtitle D units and include landfills, surface impoundments, land application units, and waste piles.

[b] These are the correct totals. The table entries may not add to their respective totals because of rounding.

SIs. This is close to the approximately 16,000 industrial SIs predicted by the census, taking into account the data gaps mentioned previously.

Table 4-56 presents results from the Industrial Facilities Survey on the number of industrial Subtitle D SIs that are used for back-up or surge capacity only, rather than for everyday waste disposal purposes. The survey results indicate that approximately 16 percent of the industrial SIs are used only for back-up.

Ownership data were provided in the census for 149,711 (78.2 percent) of the Subtitle D SIs. More than 98 percent were privately owned, as shown in Table 4-57, although local governments owned most of the municipal sewage sludge and municipal run-off SIs.

The census provided acreage information for 123, 412 (64 percent) of the SIs. As Table 4-58 shows, the majority (90.6 percent) of these impoundments were less than one acre, although about a third of mining impoundments were six acres or more. Additional SI acreage information from the Industrial Facilities Survey is presented in Table 4-59. The table indicates that most (80 percent) of the industrial SIs surveyed are less than five acres.

Census respondents supplied waste quantity data for 124,038 (64.8 percent) of the SIs. As shown in Table 4-60, more than four-fifths of these impoundments received less than 50,000 gallons each day. Fewer than 1 percent of all impoundments were reported to receive 10 million gallons or more per day.

Table 4-61 presents results from the Industrial Facilities Survey of waste quantities received in 1985 by SIs in the 17 major industries. The table also presents the percentage of the total industrial Subtitle D waste that SIs received. The survey indicates that most (96.6 percent) of the industrial waste disposed of in Subtitle D facilities is sent to SIs. Additional waste quantity information from the Industrial Facilities Survey is presented in Table 4-62, which shows the distribution of industrial establishments with SIs according to the quantity of waste disposed of in their SI during 1985. The table indicates that approximately 40 percent of all establishments with active SIs disposed of more than 10,000 tons in those SIs.

Waste Characteristics

Wastes disposed of in Subtitle D SIs are generally in liquid, sludge, or slurry form. The available information on physical and chemical characteristics of these wastes is presented in

Table 4-56. NUMBER OF ACTIVE SUBTITLE D SURFACE IMPOUNDMENTS USED ONLY FOR BACK-UP OR SURGE CAPACITY BY INDUSTRY TYPE

Industry Type	Total Number of Active Surface Impoundments	Number of Establishments with Active Surface Impoundments	Number of Establishments with Back-Up Surface Impoundments	Number of Surface Impoundments Used Only for Back-Up
Organic Chemicals	262	88	35	63
Primary Iron and Steel	383	185	17	24
Fertilizer and Agricultural Chemicals	274	113	25	55
Electric Power Generation	1,220	322	72	138
Plastics and Resins Manufacturing	292	80	32	62
Inorganic Chemicals	1,039	345	69	136
Stone, Clay, Glass, and Concrete	3,152	1,977	270	432
Pulp and Paper	918	302	88	165
Primary Nonferrous Metals	448	188	30	56
Food and Kindred Products	4,166	1,713	389	825
Water Treatment	659	330	64	73
Petroleum Refining	915	321	85	181
Rubber and Miscellaneous Products	176	126	16	21
Transportation Equipment	287	121	18	33
Selected Chemicals and Allied Products	219	53	24	58
Textile Manufacturing	741	388	72	76
Leather and Leather Prod.	102	27	4	4
Total[a]	15,253	6,681	1,308	2,403

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

Table 4-57. NUMBER OF ACTIVE SUBTITLE D SURFACE IMPOUNDMENTS BY OWNERSHIP CATEGORY

Ownership Category	Surface Impoundment Type							Total Per Ownership Category
	Municipal Sewage Sludge	Municipal Run-off	Industrial Waste	Agricultural Waste	Mining Waste	Oil or Gas Waste	Other	
Response Rate (percent)	95%	100%	66%	92%	69%	69%	48%	78%
Owned by State Government	19 (1.0%)	0	94 (0.9%)	25 (0.2%)	0	0	20 (0.4%)	158 (0.1%)
Owned by Local Government	1,327 (72.4%)	368 (75.4%)	71 (0.7%)	0	5 (0.04%)	0	663 (12%)	2,434 (1.6%)
Owned by Federal Government	42 (2.3%)	5 (1.0%)	74 (0.7%)	3 (0.002%)	0	0	11 (0.2%)	135 (0.1%)
Privately Owned	446 (24.3%)	115 (23.6%)	10,519 (97.8%)	15,733 (99.8%)	13,625 (99.96%)	101,884 (100%)	4,662 (87%)	146,984 (98.2%)
Total Number of Surface Impoundments by Type[a]	1,834 (100%)	488 (100%)	10,758 (100%)	15,761 (100%)	13,630 (100%)	101,884 (100%)	5,356 (100%)	149,711 (100%)

SOURCE: Reference 1.

[a] Percentages are rounded and may not total 100 percent.

Table 4-58. NUMBER OF ACTIVE SUBTITLE D SURFACE IMPOUNDMENTS BY ACREAGE CATEGORY

Acreage Category (acres)	Surface Impoundment Type							Total Per Acreage Category
	Municipal Sewage Sludge	Municipal Run-off	Industrial Waste	Agricultural Waste	Mining Waste	Oil or Gas Waste	Other	
Response Rate	68%	71%	40%	69%	33%	73%	47%	64%
Less than 0.1	138 (11.1%)	43 (12.4%)	705 (10.8%)	560 (4.7%)	320 (5.0%)	36,575 (39.9%)	4,833 (91.7%)	43,174 (35%)
0.1 - 0.4	524 (42.0%)	123 (35.5%)	1,627 (24.8%)	5,843 (49.5%)	439 (6.9%)	48,318 (52.7%)	241 (4.6%)	57,115 (46.3%)
0.5 - 0.9	405 (32.5%)	92 (26.6%)	2,205 (33.6%)	2,445 (20.7%)	927 (14.4%)	5,316 (5.8%)	137 (2.6%)	11,527 (9.3%)
1 - 5	155 (12.4%)	67 (19.4%)	1,113 (17.0%)	2,791 (23.6%)	2,679 (41.6%)	1,244 (1.4%)	42 (0.8%)	8,091 (6.5%)
6 - 10	16 (1.3%)	16 (4.6%)	458 (7.0%)	68 (0.6%)	1,801 (28.0%)	237 (0.3%)	15 (0.3%)	2,611 (2.1%)
11 - 100	4 (0.3%)	5 (1.4%)	380 (5.8%)	102 (0.9%)	257 (4.0%)	27 (0.03%)	2 (0.04%)	777 (0.06%)
Greater than 100	5 (0.4%)	0	70 (1.1%)	0	17 (0.3%)	25 (0.03%)	0	117 (0.1%)
Total[a]	1,247 (100%)	346 (100%)	6,558 (100%)	11,809 (100%)	6,440 (100%)	91,742 (100%)	5,270 (100%)	123,412 (100%)

SOURCE: Reference 1.

[a] Percentages are rounded and may not total 100 percent.

Table 4-59. NUMBER OF INDUSTRIAL SUBTITLE D ESTABLISHMENTS WITH ACTIVE SURFACE IMPOUNDMENTS BY INDUSTRY TYPE AND TOTAL AREA OF SURFACE IMPOUNDMENTS IN EACH ESTABLISHMENT

Industry Type	Number of Establishments by Area of Surface Impoundments								Total Establishments Per Industry Type[a]
	Less than 0.1 Acre	0.1-0.49 Acre	0.5-0.99 Acre	1-5 Acres	6-10 Acres	11-50 Acres	51-100 Acres	More than 100 Acres	
Organic Chemicals	7	16	11	20	25	7	0	2	88
Primary Iron and Steel	38	35	15	41	11	39	3	4	185
Fertilizer and Agricultural Chemicals	44	18	4	29	3	9	3	4	113
Electric Power Generation	56	17	13	73	22	55	33	51	321
Plastics and Resins Manufacturing	9	16	5	28	8	13	0	1	80
Inorganic Chemicals	31	75	70	86	24	33	9	17	345
Stone, Clay, Glass, and Concrete	885	331	106	408	102	128	12	5	1,976
Pulp and Paper	34	38	36	43	11	84	18	39	302
Primary Non-ferrous Metals	53	19	19	27	37	10	5	17	188
Food and Kindred Prod.	253	316	258	529	120	149	22	65	1,713
Water Treatment	37	64	30	157	30	13	1	0	331
Petroleum Refining	68	84	16	100	16	27	4	6	320
Rubber and Miscellaneous Products	67	12	15	31	0	1	0	0	126
Transportation Equipment	54	13	14	30	4	3	1	0	120
Selected Chemicals and Allied Products	11	3	5	18	7	9	0	0	53
Textile Manufacturing	134	77	18	133	6	12	8	0	388
Leather and Leather Products	4	0	4	9	6	3	0	0	27
Total[a]	1,784	1,133	641	1,760	435	596	119	210	6,677[b]

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

[b] Overall response rate for this table is 99 percent.

Table 4-60. NUMBER OF SUBTITLE D SURFACE IMPOUNDMENTS BY SURFACE IMPOUNDMENT TYPE AND AMOUNT OF WASTE

Amount of Waste Received (in thousands)	Surface Impoundment Type							Total Per Amount of Waste Received for Each Category
	Municipal Sewage Sludge	Municipal Run-off	Industrial Waste	Agricultural Waste	Mining Waste	Oil or Gas Waste	Other	
Response Rate	79%	58%	40%	70%	31%	74%	46%	65%
50 or fewer gallons/day	1,392 (95.7%)	215 (75.7%)	2,998 (46.1%)	11,074 (92.9%)	2,372 (39.2%)	79,096 (85.3%)	5,013 (97.8%)	102,160 (82.3%)
50 - 99 gallons/day	50 (3.4%)	58 (20.4%)	1,202 (18.5%)	831 (7.0%)	619 (10.2%)	266 (0.3%)	71 (1.4%)	3,097 (2.5%)
100 - 499 gallons/day	14 (1.0%)	0	935 (14.4%)	21 (0.2%)	1,136 (18.8%)	13,316 (14.4%)	36 (0.7%)	15,458 (12.5%)
500 - 999 gallons/day	2 (0.2%)	3 (1.1%)	817 (12.6%)	0	630 (10.4%)	0	5 (0.1%)	1,457 (1.2%)
1,000 - 9,999 gallons/day	0	8 (2.8%)	470 (7.2%)	0	946 (15.6%)	0	7 (0.1%)	1,431 (1.2%)
10,000 or more gallons/day	0	0	85 (1.3%)	0	350 (5.8%)	0	0	435 (0.3%)
Total[a]	1,458 (100%)	284 (100%)	6,507 (100%)	11,926 (100%)	6,053 (100%)	92,678 (100%)	2 (100%)	124,038 (100%)

SOURCE: Reference 1.

[a] Percentages are rounded and may not total 100 percent.

Table 4-61. WASTE QUANTITY DISPOSED OF IN INDUSTRIAL SUBTITLE D SURFACE IMPOUNDMENTS IN 1985 BY INDUSTRY TYPE

Industry Type[a]	Number of Establishments with Active Surface Impoundments	Waste Quantity Disposed of in Surface Impoundments (thousand tons)	Total Waste Quantity Disposed of in All Facilities (thousand tons)	Percent of Total Waste Disposed of in Surface Impoundments
Organic Chemicals	88	56,727	58,864	96.3
Primary Iron and Steel	185	1,290,649	1,300,541	99.2
Fertilizer and Agricultural Chemicals	113	154,257	165,623	93.1
Electric Power Generation	322	1,037,665	1,092,277	95.0
Plastics and Resins Manufacturing	80	177,241	180,510	98.2
Inorganic Chemicals	345	875,075	919,725	95.1
Stone, Clay, Glass, and Concrete	1,977	605,168	621,974	97.3
Pulp and Paper	302	2,235,418	2,251,700	99.3
Primary Nonferrous Metals	188	56,559	67,070	84.3
Food and Kindred Products	1,713	293,524	373,517	78.6
Water Treatment	330	49,724	58,846	84.5
Petroleum Refining	321	167,885	168,632	99.6
Rubber and Miscellaneous Products	126	23,567	24,198	97.4
Transportation Equipment	121	11,789	12,669	93.1
Selected Chemicals and Allied Products	53	62,440	67,987	99.1
Textile Manufacturing	388	252,931	253,780	99.7
Leather and Leather Products	27	3,214	3,234	99.4
Total[a]	6,681	7,353,834	7,616,149	96.6

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

Table 4-62. NUMBER OF ESTABLISHMENTS WITH SURFACE IMPOUNDMENTS BY INDUSTRY AND WASTE QUANTITY DISPOSED OF IN THEM IN 1985

Industry Type	Number of Establishments by Waste Quantity Disposed of in Them in 1985 (tons)								Total Establishments Per Industry Type[a]
	Less Than 3	3-9	10-99	100-499	500-999	1,000-4,999	5,000-10,000	Greater Than 10,000	
Organic Chemicals	1	2	2	12	1	11	13	45	86
Primary Iron and Steel	1	1	37	18	3	24	10	89	182
Fertilizer and Agricul. Chemicals	3	1	37	9	3	6	3	47	110
Electric Power Generation	5	3	29	29	7	20	7	207	306
Plastics and Resins Manufacturing	3	2	4	6	1	8	2	50	77
Inorganic Chemicals	3	1	25	34	14	83	32	145	340
Stone, Clay, Glass, and Concrete	42	106	419	594	194	217	76	290	1,939
Pulp and Paper	9	23	0	29	3	19	15	201	301
Primary Nonferrous Metals	6	5	38	18	2	51	10	55	186
Food and Kindred Products	13	30	105	215	54	353	129	799	1,700
Water Treatment	0	0	34	34	5	17	32	207	329
Petroleum Refining	30	4	60	12	10	70	8	117	310
Rubber and Miscellaneous Products	41	1	22	1	10	1	3	46	126
Transportation Equipment	7	0	19	29	2	9	8	44	118
Selected Chemicals and Allied Products	2	0	2	3	4	4	5	33	52
Textile Manufacturing	1	16	39	1	11	21	16	283	388
Leather and Leather Products	0	0	3	3	1	0	1	18	27
Total[a]	168	197	877	1,049	325	916	369	2,677	6,578[b]

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

[b] Overall response rate for this table is 98.5 percent.

Chapter 3 of this report. Table 4-63 presents results from the Industrial Facilities Survey of the total number of SIs receiving on-site SQG hazardous waste for each of 17 major industries. According to the survey, most SQGs do not dispose of their hazardous waste in on-site SIs.

4.2.2 DESIGN AND OPERATION OF SURFACE IMPOUNDMENTS

The following discussion of design and operating characteristics of Subtitle D SIs summarizes the pertinent data collection efforts. The information is organized under the topics of design, operation and maintenance, and environmental monitoring characteristics. Table 4-64 presents the number of Subtitle D SIs using various types of release prevention methods, according to the 1984 census. With a few exceptions, release prevention is not a frequently used waste management method. Further detail on this topic is provided throughout the subsection.

Surface Impoundment Design

The design of an SI may be a complex engineering activity in which waste characteristics, facility usage characteristics, and site characteristics are considered in the specification of design features. This subsection will outline the major environmental protection features of an SI design. These features include liners, run-on/run-off controls, leachate detection systems, cover and closure characteristics, and location factors.

Liners

Liners constructed of low-permeability materials are used to prevent waste migration through impoundment floors and sidewalls. Since liner use for landfills and SIs is similar, descriptions of soil, membrane, and composite liners are analogous to those provided in the landfill subsection (Subsection 4.1.3). Subtitle D census data on liner use status indicate that less than one-third of active SIs are lined (see Table 4-64).

Soil liners for SIs are similar to those for landfills, although SI designs usually consider the additional effects of hydraulic head on the integrity of the liner. The Subtitle D census indicates that 27 percent of active Subtitle D SIs use soil liners. Soil liner use is most frequent among agricultural waste impoundments (54 percent), followed by other waste (44 percent), municipal run-off (29 percent), oil and gas waste (27 percent), municipal sewage sludge (26 percent), industrial waste (17 percent), and mining waste (4 percent) impoundments (see Table 4-64). No data were available to describe the quality of the soil liners used in these impoundments.

Table 4-63. NUMBER OF SMALL-QUANTITY-GENERATOR INDUSTRIAL ESTABLISHMENTS THAT DISPOSE OF THEIR SMALL-QUANTITY-GENERATOR WASTE IN THEIR SURFACE IMPOUNDMENTS BY INDUSTRY TYPE

Industry Type	Number of Establishments with Active Surface Impoundments	Number of Establishments that are SQGs with Surface Impoundments	Number of SQG Establishments Disposing of SQG Waste in Their Surface Impoundments
Organic Chemicals	88	13	3
Primary Iron and Steel	185	26	9
Fertilizer and Agricultural Chemicals	113	40	4
Electric Power Generation	322	180	15
Plastics and Resins Manufacturing	80	11	4
Inorganic Chemicals	345	117	2
Stone, Clay, Glass, and Concrete	1,977	550	42
Pulp and Paper	302	114	35
Primary Nonferrous Metals	188	64	10
Food and Kindred Products	1,713	570	84
Water Treatment	330	74	10
Petroleum Refining	321	165	27
Rubber and Miscellaneous Products	126	16	10
Transportation Equipment	121	17	1
Selected Chemicals and Allied Products	53	6	3
Textile Manufacturing	388	171	50
Leather and Leather Products	27	9	0
Total[a]	6,681	2,143	309

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

Table 4-64. NUMBER OF SUBTITLE D SURFACE IMPOUNDMENTS USING VARIOUS TYPES OF RELEASE PREVENTION METHODS

Management Method	Municipal Sewage Sludge	Municipal Run-off	Industrial Waste	Agricultural Waste	Mining Waste	Oil or Gas Waste	Other (e.g., drinking water treatment sludges)	Total Surface Impoundments Per Management Method
Synthetic Liners (e.g., membrane)	76 (3.9%)	23 (4.7%)	756 (4.7%)	60 (0.3%)	200 (1.0%)	2,950 (2.4%)	6 (0.1%)	4,071 (2.1%)
Natural Liners (e.g., clay)	508 (26.2%)	140 (28.7%)	2,818 (17.4%)	9,299 (54.2%)	868 (4.4%)	33,768 (27%)	4,835 (44%)	52,236 (27%)
Leak Detection Systems	32 (1.7%)	37 (7.6%)	896 (5.5%)	26 (0.2%)	335 (1.7%)	1,406 (1.1%)	0	2,732 (1.4%)
Overtopping Controls	589 (30.4%)	269 (55.1%)	3,672 (23%)	6,713 (39.1%)	4,144 (20.9%)	28,541 (23%)	4,733 (43%)	48,661 (25%)
Waste Restrictions (ban on certain Subtitle D waste types)	634 (32.9%)	71 (14.5%)	2,685 (17%)	8,371 (48.8%)	4,358 (22.0%)	30,509 (24.4%)	4,736 (42.6%)	51,364 (26.8%)
Discharge Permits	522 (26.6%)	16 (3.3%)	4,738 (29.2%)	2,018 (11.8%)	4,970 (25.7%)	46,491 (37.2%)	171 (1.5%)	58,926 (30.7%)
All Management Methods[a]	1,938	488	16,232	17,159	19,813	125,074	11,118	191,822

SOURCE: Reference 1.

[a] Some establishments use more than one management method. Therefore, the percentages may add to more than 100.

Membrane liners are, ideally, impermeable to liquid wastes, so the effect of hydraulic head is reduced. Shultz et al.[39] have demonstrated the technical feasibility of retrofitting SIs with membrane liners using a "pull-through" technique with a flexible chlorosulfonated polyethylene membrane. The Subtitle D census indicates that just over 2 percent of the active Subtitle D SIs use membrane or synthetic liners. Between 2 and 5 percent of industrial waste, municipal run-off, municipal sewage sludge, and oil and gas waste impoundments have membrane liners; while 1 percent or less of mining waste, agricultural waste, and other waste impoundments use them (see Table 4-64). No data were available that described the membrane liners used in the lined impoundments.

Run-on/Run-off Controls

Dikes, channels, and berms control run-on and run-off by damping, diverting, and/or slowing storm water flow into and out of SIs. Design requirements are dictated by site topography, normal climate, and expected extreme weather conditions. Dikes are used for impoundment sidewall construction and run-off control. Lined sidewall dikes on fill and filled/excavated impoundments serve to ensure slope stability and prevent lateral seepage. Both kinds of dikes are designed to provide surface drainage control, meet stability criteria and resist wind-driven wave erosion, rain erosion, burrowing animals, and tree roots.

Channels and berms are used in conjunction with dikes to minimize run-off, erosion, and infiltration. Channels may be constructed of concrete, sod, corrugated metal, or admix materials. They divert run-on from impoundments, and their design is determined by site topography and expected climatic conditions. Berms are flattened embankments surrounding impoundments designed to lessen run-on velocity and allow sufficient room for the equipment used in liner installation and maintenance.

The Subtitle D census reported that overtopping controls are used at 25 percent of SIs (see Table 4-64). The census did not distinguish between different types of overtopping controls, and no other data concerning run-on/run-off control technology uses were available. Overtopping controls are used most frequently among municipal run-off impoundments (55 percent), followed by other waste (43 percent), agricultural waste (39 percent), municipal sewage sludge (30 percent), industrial waste (23 percent), oil and gas waste (23 percent), and mining waste (21 percent) impoundments.

Leak Detection Systems

Leak detection systems indicate liner failure and subsequent waste migration from lined SIs. The Subtitle D census reports that leak detection systems are found at only 1.4 percent of active impoundments. As shown in Table 4-64, the highest rate of leak detection system use is with municipal run-off (7.6 percent) and industrial waste impoundments (5.5 percent).

Impoundment wastes exhibit phenomena that distinguish them from normal ground-water conditions. Leak detection requires the discovery of the wastes' distinctive phenomena outside the impoundment boundaries. Distinctive phenomena that yield to modern detection systems include changes in specific conductance, the presence of subgrade and impoundment materials, characteristics of ground-water flow fields, and liner and soil distress.

Cover and Closure Characteristics

When an SI has reached the end of its useful life, and after the liquid wastes have been dewatered and otherwise treated, a permeable or impermeable cap may be installed. The specific features of an SI cover design depend upon the intended final use of the waste site as dictated in the closure plan. Cover designs for dewatered and treated SI wastes are the same as cover designs for landfilled waste. Characteristics of landfill covers were discussed previously.

In most cases, impoundment closure follows a procedure of dewatering, sludge removal and disposal, liner repair or removal, dike repair and contaminated soil removal, monitoring system installation, backfill, cover, and surface reclamation.[40] No data were available on the number of cover systems being used.

Location Factors

Physical location factors (site and surrounding topography, climate, and hydrogeologic setting) present the final line of defense for contaminant control. No data were available concerning the location characteristics of different facilities or the numbers of SIs employing location factors in their designs. State and territorial location requirements are discussed in Chapter 5.

Surface Impoundment Operation and Maintenance

As with landfills, operation and maintenance of an SI is an ongoing project involving equipment, materials, and personnel. Because of the nature of liquid wastes, operation and maintenance of an SI is less labor and equipment intensive than operation and maintenance of a landfill, and operating costs are generally lower. Subtitle D census statistics for release prevention and management methods that may be used during SI operations are presented in Table 4-64. Almost 27 percent of SIs have waste restrictions, and about 30 percent have discharge permits.

Limited information is available to indicate the incidence of other operating and maintenance features. Operation and maintenance plans for SIs may include staff structure and requirements, facility description and design parameters, emergency procedures, operation variables and procedures, troubleshooting procedures, preventive maintenance procedures, personnel safety requirements and procedures, equipment maintenance records, permissible and unacceptable waste lists, and an additional record of all additions, deletions, or revisions of procedures.[25] Maintenance of the physical plant will include control of design, construction, construction materials, wastes received, impoundment performance, liner condition, earth work condition, vegetation, rodents, inspections, and unacceptable practices.[25]

Environmental Monitoring at Surface Impoundments

This section presents pertinent environmental monitoring characteristics of Subtitle D SIs. Environmental monitoring may be performed in three media: ground water, surface water, and air. The Subtitle D census provides an indication of active Subtitle D SI monitoring activity.

Ground-Water Systems and Parameters

The purpose of ground-water monitoring is to determine the presence or extent of contaminant migration from the impoundment. Consideration for ground-water monitoring systems and parameters for SIs are identical to design consideration for landfill ground-water monitoring and can be found in Section 4.1.3. Table 4-65 indicates that about 4 percent of all impoundments have ground-water monitoring systems. Mining waste impoundments were reported to have these systems more often than other impoundments.

Table 4-65. NUMBER OF ACTIVE SURFACE IMPOUNDMENTS WITH MONITORING SYSTEMS[a]

Surface Impoundment Type	Number of Surface Impoundments by Monitoring System		
	Ground-Water	Surface-Water	Air Emissions
Municipal Sewage Sludge	131 (6.8%)	50 (2.6%)	10 (0.5%)
Municipal Run-off	192 (39.3%)	57 (11.7%)	0
Industrial Waste	1,396 (8.6%)	3,151 (19.4%)	73 (0.4%)
Agricultural Waste	44 (0.3%)	135 (0.8%)	1 (<0.1%)
Mining Waste	5,399 (27%)	8,679 (43.8%)	15 (0.1%)
Oil and Gas Waste	165 (0.1%)	20,030 (16.0%)	25 (<0.1%)
Other	7 (0.1%)	133 (1.2%)	0
Total	7,334 (3.8%)	32,235 (16.8%)	124 (0.1%)

SOURCE: Reference 1.

[a] Percentages are total number of surface impoundments having the specific monitoring system divided by the total number of surface impoundments of that type.

Surface Water Systems and Parameters

The Subtitle D census indicates that approximately 17 percent of Subtitle D impoundments presently have surface water monitoring systems. Mining waste (44 percent) and industrial waste (19 percent) have higher percentages of surface water monitoring than do the other impoundment types (see Table 4-65). The proximity of waste SIs to surface water and drainage patterns determine the necessity of surface water monitoring. Sampling programs generally include upstream stations to collect adequate background water quality data and downstream stations in areas of most likely contamination.

Air Monitoring Systems and Parameters

Nonhazardous waste SIs do not generally contain explosive or highly volatile gases. Accordingly, Table 4-65 indicates that only 0.1 percent of active Subtitle D SIs have air monitoring systems. Excluding methane monitoring (which is not relevant to SIs), the air monitoring systems and parameters at SIs are identical to those used for landfill air monitoring and are described in the landfill section.

4.2.3 ANALYSIS OF ENVIRONMENTAL AND HUMAN HEALTH IMPACTS AT SURFACE IMPOUNDMENTS

This subsection presents data relating to environmental and human health impacts of Subtitle D SIs, and has the same objectives as Subsection 4.1.4. Table 4-66 presents Subtitle D census data relating to ground-water, surface water, and air impacts at Subtitle D SIs. The table also presents statistics on State inspections and on the numbers of SIs with monitoring systems. The following discussion reviews the available aggregate and case study information on the impacts of ground-water, surface water, and air contamination.

Ground Water

Ground-water impacts of Subtitle D SIs were not described in detail in any of the data collection efforts, nor were they described in any of the literature reviewed for this study. However, the census presented data on ground-water-related permit violations at Subtitle D SIs. No case studies were evaluated for ground-water impacts associated with SIs.

Table 4-66. AGGREGATE DATA RELATING TO ENVIRONMENTAL CONTAMINATION AT SURFACE IMPOUNDMENTS

	Number of Subtitle D Surface Impoundments by Type							Total Surface Impoundments Per Category
	Municipal Sewage Sludge	Municipal Run-Off	Industrial Waste	Agricultural Waste	Mining Waste	Oil and Gas Waste	Other	
Total Active Facilities	1,938	488	16,232	17,159	19,813	125,074	11,118	191,822
Number of Facilities With at Least One Violation								
Ground-water contamination	35	32	416	29	48	111	6	677
Surface water contamination	24	18	279	189	249	128	22	909
Air contamination	20	12	145	21	5	10	0	213
State Inspection at Least Once Each Year[a]	1,148	350	5,541	3,334	2,366	62,724	674	76,137
Facilities With Monitoring								
Ground water	131	192	1,396	44	5,399	165	7	7,334
Surface water	50	57	3,151	135	8,679	20,030	133	32,235
Air emissions	10	0	73	1	15	25	0	124

SOURCE: Reference 1.

[a] These data include numbers cited by States for frequencies ranging from once a year to more than four times a year. They exclude less frequent inspections and entries under the questionnaire category of "other."

Census Data

Table 4-66 presents data showing that few SIs monitor ground water. This table also presents the number of facilities with at least one ground-water protection standard violation and the number of facilities with inspections at least once each year. The census reported 416 ground-water violations at industrial SIs and lesser numbers at other types of SIs. Thirty-two ground-water contamination violations were reported at municipal run-off SIs.

These values and those for other types of SIs may understate the total number of violations substantially, since of the active industrial and municipal run-off SIs, only 9 percent and 39 percent, respectively, had ground-water monitoring programs. For these and other reasons cited previously (in the discussion of impacts at landfills), the number of reported violations is an imperfect measure of environmental impacts.

Surface Water

Surface water impacts of Subtitle D surface impoundments were not described in detail in any of the data collection efforts or literature reviews. The census presents data on surface-water-related violations at Subtitle D surface impoundments. In the absence of case studies or data regarding surface water impacts associated with surface impoundments, actual public health or environmental impacts associated with contamination from this type of facility cannot be made. No case studies were evaluated for surface water impacts associated with SIs.

Census Data

Table 4-66 shows that about 17 percent of all impoundments monitor surface water. The table also indicates that 24 municipal sewage sludge surface impoundments were reported by the State to have at least one surface water contamination violation, compared to 279 industrial facilities, 189 agricultural units, and 249 mining waste units, contributing to a total of 909 SI units with violations in 1984.

Air

Air impacts at Subtitle D SIs were not described in detail in any of the data collection efforts or literature reviews. The census does present data on air-related violations at Subtitle D SIs. No case studies that examine actual impacts upon air quality due to the presence of an SI were available for this study. In the absence of such data the nature and significance of impacts associated with these occurrences cannot be evaluated. However, the reports of contamination violations indicate that these problems do exist.

Census Data

Table 4-66 indicates that little air monitoring is performed at SIs. Twenty municipal sewage sludge SIs were reported that have at least one air contamination violation compared to 145 industrial facilities, 21 agricultural units, and 5 mining waste units, contributing to a total of 213 SI units with at least one violation in 1984.

4.3 LAND APPLICATION UNITS

This section presents data on Subtitle D land application units (LAUs). The topics covered include general profile, design and operation, and environmental impacts at LAUs.

4.3.1 GENERAL PROFILE

The Subtitle D census provided general information on the numbers, ownership, acreage, and waste volumes of LAUs. Information on waste characteristics was available from other sources. The Subtitle D census defined LAUs as:

> A part of an establishment at which waste is applied onto or incorporated into the soil surface for the purpose of beneficial use or waste treatment and disposal. Land application is often referred to as landfarming or landspreading. Specifically excluded from this definition are manure spreading operations.

This definition is broken down further into:

> Municipal sewage sludge land application units, which primarily receive sewage sludge from publicly owned or privately owned domestic sewage treatment facilities, including sludge from domestic septic tanks (wastewater LAUs are not included in the census). These LAUs are divided into two types: high-application units, where the application rate exceeds the nutrient needs of crops, and low-application units, where the application rate is based on crop nutrient needs.

Industrial waste land application units, which receive waste (including sludge or wastewater) primarily from factories, processing plants, and other manufacturing or commercial activities.

Oil and gas land application units, which receive waste generated by oil and gas exploration and extraction operations--e.g., drilling muds.

Other land application units, which receive Subtitle D wastes but do not fall into any of the above categories--e.g., a drinking water treatment waste LAU.

For each type of LAU, Subtitle D census data were collected on total numbers, ownership, acreage, and amount of wastes received.

Numbers of Land Application Units

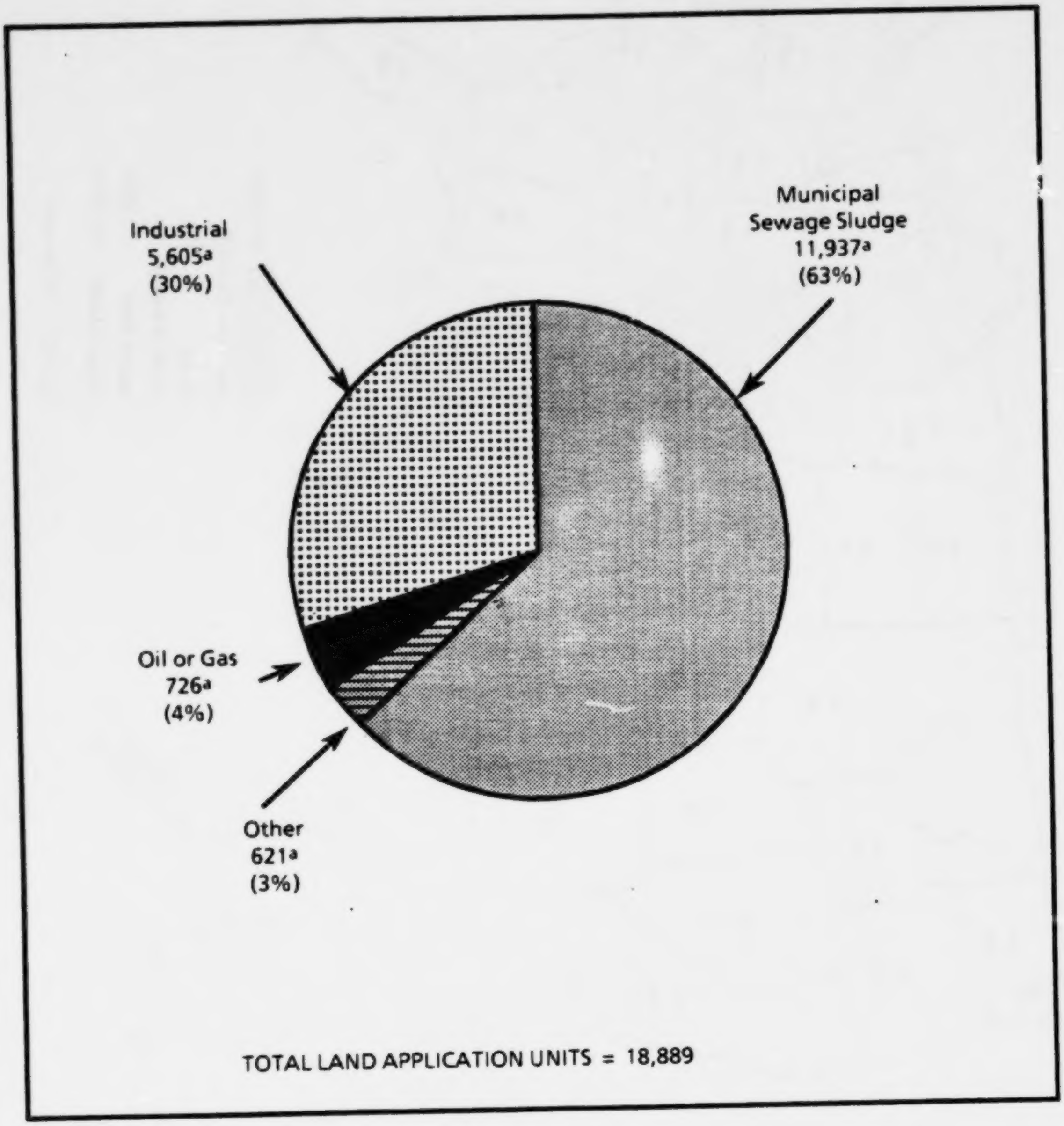
Respondents typically rated the quality of the data on the numbers of LAUs in the fair, poor, or very poor range. According to census results, there were 18,889 Subtitle D LAUs located at 12,312 establishments in the United States in 1984. Municipal sewage sludge units accounted for about two-thirds of this total. Figure 4-19 presents the number and relative share of the total for each of the four types of LAUs. The total estimated number of active Subtitle D LAUs in 1984 for each State and territory is shown on the map presented in Figure 4-20. Wisconsin has the highest number of Subtitle D LAUs (4,181), followed by Michigan (2,501), Pennsylvania (2,400), Indiana (1,300), and Minnesota (850).

Data on the number of industrial establishments with any active Subtitle D units, the number of establishments with active LAUs, the number of active LAUs, and the number of closed LAUs are shown in Table 4-67.

Ownership of Land Application Units

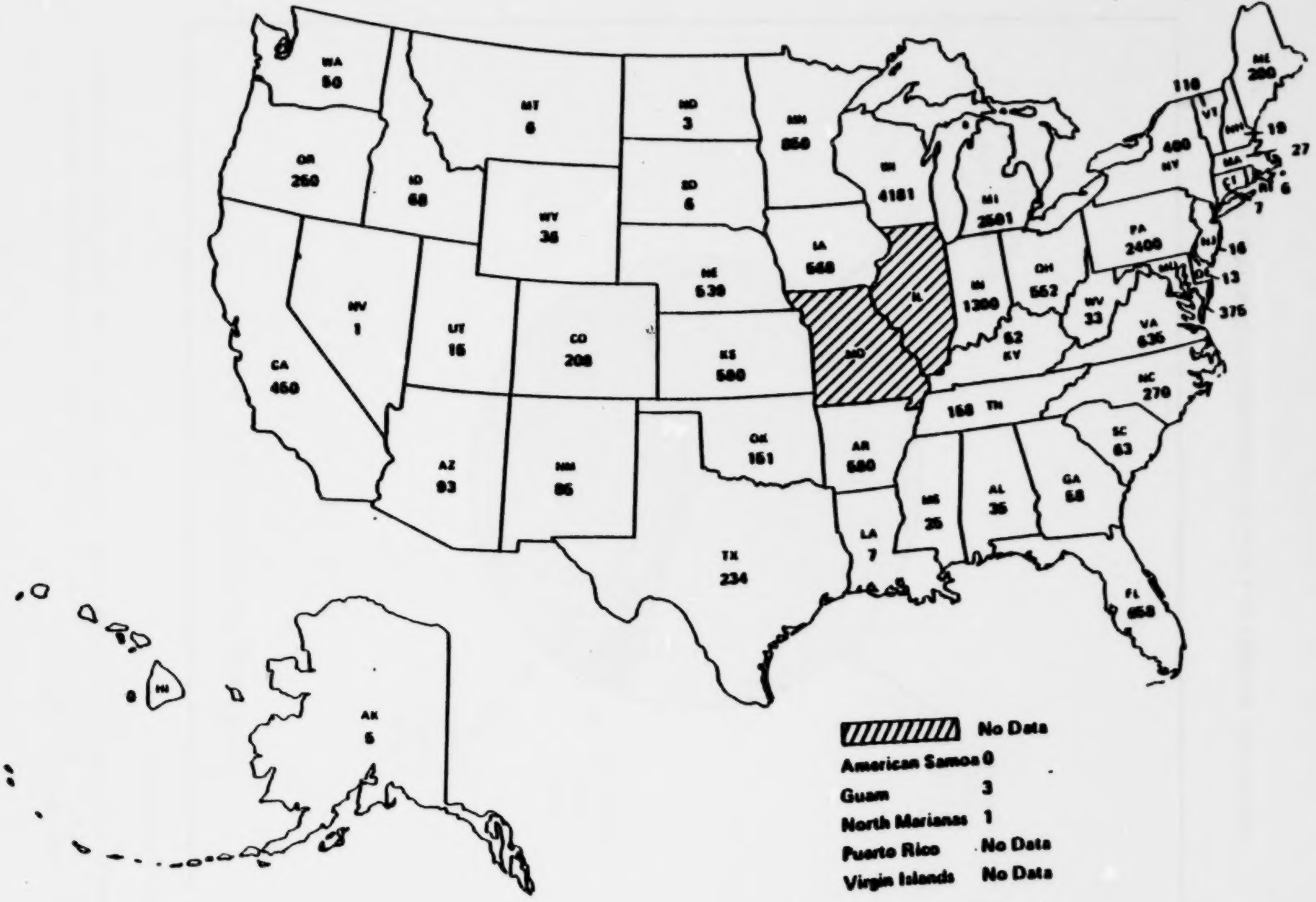
Ownership data were reported in the census for 18,782 (99.4 percent) of the total Subtitle D LAUs, and are presented in Table 4-68. The high-rate application and low-rate application data do not equal the total municipal sewage sludge figures because States that reported municipal sewage sludge data did so in different ways. Some States reported one number for the total municipal sewage sludge facilities, while others reported the total number of facilities according to the

Figure 4-19. NUMBER OF SUBTITLE D LAND APPLICATION UNITS BY TYPE



SOURCE: Reference 1.

[a] No estimates of municipal sewage sludge LAUs obtained for IL, LA, MO or WV; no estimates of industrial waste LAUs obtained for IL, LA, MO, or MT; and no estimates of oil or gas waste LAUs obtained for IL, MO, or MT.



SOURCE: Reference 1.

Figure 4-20. NUMBER OF SUBTITLE D LAND APPLICATION UNITS BY STATE

Table 4-67. NUMBER OF INDUSTRIAL ESTABLISHMENTS WITH SUBTITLE D LAND APPLICATION UNITS AND NUMBER OF LAND APPLICATION UNITS BY INDUSTRY TYPE

Industry Type	Total Number of Active Subtitle D Units[a]	Number of Active Land Application Units	Number of Establishments with Active Land Application Units	Number of Establishments with Closed Land Application Units
Organic Chemicals	385	27	24	8
Primary Iron and Steel	1,124	76	53	10
Fertilizer and Agricultural Chemicals	515	160	95	27
Electric Power Generation	1,528	43	34	6
Plastics and Resins Manufacturing	373	17	15	10
Inorganic Chemicals	1,281	24	16	27
Stone, Clay, Glass, and Concrete	7,247	309	188	64
Pulp and Paper	1,548	139	75	38
Primary Nonferrous Metals	880	9	8	18
Food and Kindred Products	8,029	3,128	1,375	229
Water Treatment	974	147	102	30
Petroleum Refining	1,249	114	45	48
Rubber and Miscellaneous Products	392	16	16	21
Transportation Equipment	723	11	10	20
Selected Chemicals and Allied Products	298	17	15	11
Textile Manufacturing	944	72	65	24
Leather and Leather Products	164	0	0	10
Total[b]	27,654	4,308	2,136	601

SOURCE: Reference 2.

[a] These numbers correspond to the total universe of active Subtitle D units and include landfills, surface impoundments, land application units, and waste piles.

[b] These are the correct totals. The table entries may not add to their respective totals because of rounding.

Table 4-68. NUMBER OF SUBTITLE D LAND APPLICATION UNITS BY OWNERSHIP CATEGORY

Land Application Unit Type	Response Rate (Percent)	Ownership Category				Total Land Application Units per Type
		State Government	Local Government	Federal Government	Privately Owned	
Municipal Sewage Sludge at High Application Rates[a]	98	2 (0.8%)	48 (20.3%)	0	187 (78.9%)	237 (100%)
Municipal Sewage Sludge at Low Application Rates[a]	99	72 (0.7%)	1,028 (10.6%)	17 (0.2%)	8,570 (88.5%)	9,687 (100%)
Total Municipal Sewage Sludge[a]	99	104 (0.9%)	1,524 (12.9%)	72 (0.6%)	10,145 (85.6%)	11,845 (100%)
Industrial Waste	99	1 (0.1%)	18 (0.3%)	13 (0.2%)	5,558 (99.4%)	5,590 (100%)
Oil or Gas Waste	100	1 (0.1%)	6 (0.8%)	16 (2.2%)	703 (96.8%)	726 (100%)
Other	100	10 (1.6%)	26 (4%)	9 (1.4%)	576 (92.8%)	621 (100%)
Total	99	116 (0.3%)	1,574 (8.4%)	110 (0.6%)	16,982 (90.4%)	18,782 (100%)

SOURCE: Reference 1.

[a] High-rate application and low-rate application do not equal the total municipal sewage sludge figures because some States do not distinguish between high and low application rates.

application rate category (high or low). As Table 4-68 makes clear, the great majority of all kinds of LAUs are privately owned.

Acreage of Land Application Units

Acreage information was supplied in the Subtitle D census for 15,576 LAUs (82.4 percent). Although three-quarters of "other" LAUs were greater than 100 acres, more than half of municipal sewage sludge, industrial waste, and oil and gas waste LAUs were less than 50 acres. These acreage data for each type of LAU and for total LAUs are presented in Table 4-69.

Additional LAU acreage information is available from the Industrial Facilities Survey, and is presented in Table 4-70. The survey indicates that more than half of the industrial facility LAUs were less than 50 acres.

Waste Volumes Handled by Land Application Units

Census information on the amounts of waste received was reported for 12,020 (63.6 percent) of the Subtitle D LAUs. Most LAUs received less than 50 tons of waste (dry weight) in 1984, as shown in Table 4-71, although the majority of oil or gas waste LAUs received 100 to 999 tons during the year. Table 4-72 presents results from the Industrial Facilities Survey of waste quantities received in 1985 by LAUs in the 17 major industries surveyed. The table also presents the percentage of the total industrial Subtitle D waste that LAUs receive. The survey indicates that very little of the total waste produced by the 17 industries and disposed of in Subtitle D facilities goes to LAUs.

Additional LAU waste quantity information from the Industrial Facilities Survey is presented in Table 4-73, which shows the distribution of industrial establishments with LAUs according to the quantity of waste disposed of in their LAUs during 1985. Most of the industries received more than 100,000 tons in 1985.

A study currently being conducted on food processing and pulp and paper industry (SIC 20 and SIC 26) LAUs provided some preliminary information[39] on waste volumes. To date, 117 land treatment sites have been contacted for the study. Seventy-two of these sites were in the food processing category. Because of the limited number of sites contacted thus far, the information presented should not be interpreted as representative of land treatment practices of either industrial category. The specific industries and the number of sites contacted are listed in Table 4-74. Both wastewater and solid wastes were applied to the land at these facilities. Over 16 billion gallons

Table 4-69. NUMBER OF SUBTITLE D LAND APPLICATION UNITS BY ACREAGE CATEGORY

Land Application Unit Type	Response Rate (percent)	Number of Units by Size				Total Land Application Units per Type[a]
		Less Than 10 Acres	10 - 49 Acres	50 - 99 Acres	100 Acres or More	
Municipal Sewage Sludge at High Application Rates[b]	98	96 (40.7%)	57 (24.2%)	64 (27.1%)	19 (8.0%)	236 (100%)
Municipal Sewage Sludge at Low Application Rates[b]	78	1,503 (19.6%)	3,339 (43.6%)	1,476 (19.3%)	1,336 (17.5%)	7,654 (100%)
Total Municipal Sewage Sludge[b]	82	2,077 (21.2%)	4,567 (46.5%)	1,789 (18.2%)	1,378 (14.0%)	9,811 (100%)
Industrial Waste	96	681 (15.4%)	1,805 (40.9%)	1,462 (33.1%)	470 (10.6%)	4,418 (100%)
Oil or Gas Waste	100	568 (78.2%)	69 (9.5%)	44 (6.1%)	45 (6.2%)	726 (100%)
Other	100	154 (24.8%)	7 (1.1%)	6 (1.0%)	454 (73.1%)	621 (100%)
Total	82	3,480 (22.3%)	6,448 (41.4%)	3,301 (21.2%)	2,347 (15.1%)	15,576 (100%)

SOURCE: Reference 1.

[a] Percentages are rounded and may not total 100 percent.

[b] High-rate application and low-rate application do not equal the total municipal sewage sludge figures because some states do not distinguish between high and low application rates.

Table 4-70. NUMBER OF ACTIVE INDUSTRIAL SUBTITLE D ESTABLISHMENTS WITH LAND APPLICATION UNITS BY INDUSTRY TYPE AND TOTAL AREA OF LAND APPLICATION UNITS IN EACH ESTABLISHMENT

Industry Type	Number of Establishments by Land Application Unit Total Area				Total Establishments Per Industry Type[a]
	Less than 10 Acres	10 - 50 Acres	51 - 100 Acres	More than 100 Acres	
Organic Chemicals	16	2	0	6	24
Primary Iron and Steel	29	4	1	0	34
Fertilizer and Agricultural Chemicals	5	54	2	34	95
Electric Power Generation	31	2	1	0	34
Plastics and Resins Manufacturing	9	1	2	3	15
Inorganic Chemicals	7	4	2	3	16
Stone, Clay, Glass, and Concrete	144	14	30	0	188
Pulp and Paper	6	4	35	30	75
Primary Nonferrous Metals	5	2	0	1	8
Food and Kindred Products	444	350	163	407	1,364
Water Treatment	32	30	29	11	102
Petroleum Refining	13	3	1	28	45
Rubber and Miscellaneous Products	12	2	1	1	16
Transportation Equipment	9	0	1	0	10
Selected Chemical and Allied Products	7	5	3	0	15
Textile Manufacturing	50	11	0	4	65
Leather and Leather Products	0	0	0	0	0
Total[a]	818	487	271	528	2,105

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

Table 4-71. NUMBER OF SUBTITLE D LAND APPLICATION UNITS BY AMOUNT OF WASTE RECEIVED ANNUALLY

Land Application Unit Type	Response Rate (percent)	Received Less than 50 Tons per Year (dry weight)	Received 50 - 99 Tons per Year (dry weight)	Received 100 - 999 Tons per Year (dry weight)	Received 1,000 or more Tons per Year (dry weight)	Total Land Application Units Per Type[a]
Municipal Sewage Sludge at High Application Rates[b]	32	20 (26.0%)	24 (31.2%)	5 (6.5%)	28 (36.4%)	77 (100%)
Municipal Sewage Sludge at Low Application Rates[b]	52	2,727 (53.9%)	958 (18.9%)	1,050 (20.8%)	321 (6.3%)	5,056 (100%)
Total Municipal Sewage Sludge[b]	57	4,276 (63.3%)	1,043 (15.4%)	1,080 (16.0%)	355 (5.3%)	6,754 (100%)
Industrial Waste	81	3,740 (91.3%)	174 (4.2%)	151 (3.7%)	30 (0.7%)	4,095 (100%)
Oil or Gas Waste	76	81 (14.7%)	22 (4.0%)	439 (79.8%)	8 (1.5%)	550 (100%)
Other	100	319 (51.4%)	151 (24.3%)	151 (24.3%)	0	621 (100%)
Total	64	8,416 (70.0%)	1,390 (11.6%)	1,821 (15.1%)	393 (3.3%)	12,020 (100%)

SOURCE: Reference 1.

[a] Percentages are rounded and may not total 100 percent.

[b] High-rate application and low-rate application do not equal the total municipal sewage sludge figures because some States do not distinguish between high and low application rates.

Table 4-72. WASTE QUANTITY DISPOSED OF IN INDUSTRIAL SUBTITLE D LAND APPLICATION UNITS IN 1985 BY INDUSTRY TYPE

Industry Type	Number of Establishments with Active Land Application Units	Waste Quantity Disposed of in Land Application Units (Thousand Tons)	Total Waste Quantity Disposed of in all Facilities (Thousand Tons)	Percent of Total Waste Disposed of in Land Application Units
Organic Chemicals	24	1,827	58,864	3.1
Primary Iron and Steel	53	76	1,300,541	<0.01
Fertilizer and Agricultural Chemicals	95	756	165,623	0.5
Electric Power Generation	34	331	1,092,277	0.03
Plastics and Resins Manufacturing	15	166	180,510	0.09
Inorganic Chemicals	16	108	919,725	0.01
Stone, Clay, Glass, and Concrete	188	51	621,974	<0.01
Pulp and Paper	75	8,942	2,251,700	0.4
Primary Nonferrous Metals	8	373	67,070	0.6
Food and Kindred Products	1,375	75,938	373,517	20
Water Treatment	102	8,955	58,846	15
Petroleum Refining	45	396	168,632	0.2
Rubber and Miscellaneous Products	16	52	24,198	0.2
Transportation Equipment	10	0.33	12,699	<0.01
Selected Chemicals and Allied Products	15	423	62,987	0.7
Textile Manufacturing	65	763	253,780	0.3
Leather and Leather Products	0	0	3,234	0
Total[a]	2,136	99,160	7,616,149	1.3

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

Table 4-73. NUMBER OF ESTABLISHMENTS WITH LAND APPLICATION UNITS BY INDUSTRY TYPE AND WASTE QUANTITY DISPOSED OF IN THEM IN 1985

Industry Type	Number of Establishments with Land Application Units by Amount of Waste Disposed of in Them (tons)						Total Establishments per Industry Type[a]
	Less Than 10	10 - 29	30 - 49	50 - 99	100 - 1,000	Greater Than 1,000	
Organic Chemicals	0	0	0	2	4	18	24
Primary Iron and Steel	25	0	0	0	5	2	32
Fertilizer and Agricultural Chemicals	38	16	0	17	4	20	95
Electric Power Generation	2	2	0	2	3	22	32
Plastics and Resins Manufacturing	1	1	1	1	6	5	15
Inorganic Chemicals	1	0	1	3	2	9	16
Stone, Clay, Glass, and Concrete	72	2	70	0	26	9	179
Pulp and Paper	1	2	0	2	40	29	74
Primary Nonferrous Metals	1	0	0	2	1	2	6
Food and Kindred Products	298	194	1	25	232	612	1,363
Water Treatment	24	4	3	0	32	38	102
Petroleum Refining	25	1	1	2	7	9	45
Rubber and Misc. Products	10	0	0	1	1	3	16
Transportation Equipment	7	1	0	1	1	0	10
Selected Chemicals and Allied Products	0	2	1	2	4	6	15
Textile Manufacturing	0	32	0	7	10	16	65
Leather and Leather Products	0	0	0	0	0	0	0
Total[a]	504	258	79	67	380	801	2,088[b]

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

[b] Overall response rate for this table is 97.7 percent.

Table 4-74. NUMBER OF SITES CONTACTED FOR FOOD PROCESSING AND PULP AND PAPER LAND APPLICATION UNITS STUDY BY INDUSTRY TYPE

Industry Category	Number of Sites Contacted
Pulp and paper	45
Meat products	2
Dairy products	5
Canned and preserved fruits and vegetables	34
Bakery products	1
Sugar products	3
Beverages	8
Miscellaneous (food preparations, canned and cured fish, roasted coffee)	19
Total	117

SOURCE: Reference 41.

and 328 thousand dry tons of waste were handled at the 117 sites. These facilities also provided some data on ages of facilities. Ninety-two of these facilities have been in operation for less than 15 years, although six facilities have been operating for more than 30 years.

Waste Characteristics

The principal waste types that are disposed of in Subtitle D LAUs include municipal sewage sludge, industrial wastewater and sludge, and oil and gas wastes. General characteristics of these wastes are presented in Chapter 3.

Waste restrictions are widely practiced at LAUs; therefore, the chemical and physical characteristics of land-applied wastes are determined as much by facility operation or design parameters as by waste generator characteristics. Table 4-75 lists waste constituent ranges for industrial wastes that are well suited for disposal through land application. Biological oxygen demand (BOD) and chemical oxygen demand (COD) are commonly used to determine a waste's degradeability.

The municipal sewage sludge characteristics of interest to land application include solids content, total fixed dissolved solids, suspended solids, BOD, and COD. As with industrial wastes, municipal sludge characteristics define a waste's degradeability and are used to establish application rate limits.

Table 4-75. GENERAL CHARACTERISTICS OF VARIOUS INDUSTRIAL WASTEWATERS APPLIED TO LAND

Constituent	Food Processing	Pulp and Paper	Dairy
BOD, mg/l	200 - 4,000	60 - 30,000	4,000
COD, mg/l	300 - 10,000	--	--
Suspended Solids, mg/l	200 - 3,000	200 - 100,000	--
Total Fixed Dissolved Solids, mg/l	1,800	2,000	1,500
Total Nitrogen, mg/l	10 - 50	--	90 - 400
pH, dimensionless	4.0 - 12	6 - 11	5 - 7
Temperature, °F	145	195	--

SOURCE: Reference 42.

Table 4-76 presents results from the Industrial Facilities Survey on the number of industrial SQGs that dispose of their hazardous waste in on-site Subtitle D LAUs. The survey indicates that very few of the SQG industrial establishments surveyed dispose of their SQG wastes in their LAUs.

4.3.2 DESIGN AND OPERATION OF LAND APPLICATION UNITS

This section discusses design, operation and maintenance, and environmental monitoring at LAUs.

Table 4-76. NUMBER OF SMALL-QUANTITY-GENERATOR INDUSTRIAL ESTABLISHMENTS THAT DISPOSE OF THEIR SMALL-QUANTITY-GENERATOR WASTE IN THEIR LAND APPLICATION UNITS BY INDUSTRY TYPE

Industry Type	Number of Establishments with Active Land Application Units	Number of SQGs with Land Application Units	Number of SQG Establishments Disposing of SQG Waste in Their Land Application Units
Organic Chemicals	24	3	0
Primary Iron and Steel	53	43	20
Fertilizer and Agricultural Chemicals	95	20	0
Electric Power Generation	34	29	1
Plastics and Resins Manufacturing	15	1	0
Inorganic Chemicals	16	4	0
Stone, Clay, Glass, and Concrete	188	132	30
Pulp and Paper	75	20	1
Primary Nonferrous Metals	8	2	0
Food and Kindred Products	1,375	401	35
Water Treatment	102	9	5
Petroleum Refining	45	2	0
Rubber and Miscellaneous Products	16	0	0
Transportation Equipment	10	0	0
Selected Chemical and Allied Products	15	0	0
Textile Manufacturing	65	40	0
Leather and Leather Products	0	0	0
Total[a]	2,136	706	91

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

Design of Land Application Units

Many variables may affect the design of LAUs. The existing soil characteristics determine the waste types that can be used, and the waste characteristics determine the application method. This section presents design information concerning slope, run-on/run-off controls, and soil requirements.

Slope

Slope can affect the amount of soil erosion and potential run-off of applied sludge. Steep slopes are acceptable if the soil is well drained and well aerated. With very permeable soils, however, steep slopes increase the possibility of surface run-off of sludge. Rapid surface run-off and soil erosion can transport sludge-soil mixtures to surface waters. The particular wastes must also be considered. No data were available concerning various slopes at active LAUs.

Run-on/Run-off Controls

Run-on/run-off control requirements are used to protect water quality and prevent unauthorized discharge into the ground water or surface water. Selection of run-on/run-off control usually depends upon sludge application techniques. The following is a list of common techniques and practices used to control run-off:[43]

- filling of depressions from cut ridges and mounds to control ponding,
- terraces to protect lower lands,
- diversion terraces graded and grass covered to deliver water at nonerosive flows to a control discharge point,
- vegetation to control erosion and reduce surface run-off,
- collection and storage of surface run-off, and
- leachate collection and control.

Table 4-77 shows that 51 percent of the LAUs reported in the census employ run-on/run-off controls. Municipal sewage sludge LAUs are the most likely to have these controls.

Table 4-77. NUMBER OF SUBTITLE D LAND APPLICATION UNITS USING VARIOUS TYPES OF RELEASE PREVENTION METHODS

Land Application Unit Type	Number of Land Application Units by Release Prevention Management Method[a]				Total Land Application Units Per Type
	Run-on/Run-off Controls	Waste Restrictions (ban on certain Subtitle D waste types)	Waste Application Rate Limits	Restrictions on the Growing of Food-Chain Crops	
Municipal Sewage Sludge at High Application Rate	59 (24.4%)	185 (76.4%)	195 (80.6%)	198 (81.8%)	242
Municipal Sewage Sludge at Low Application Rate	4,090 (41.8%)	5,698 (58.3%)	8,164 (84%)	7,672 (78.5%)	9,779
Total Municipal Sewage Sludge[b]	5,075 (42.5%)	5,932 (49.7%)	9,437 (79.7%)	8,401 (70.4%)	11,937
Industrial Waste	3,837 (68.5%)	3,633 (64.8%)	4,085 (72.9%)	2,395 (42.7%)	5,605
Oil or Gas Waste	569 (78.4%)	122 (16.8%)	93 (12.8%)	23 (3.2%)	726
Other	164 (26.4%)	554 (89.2%)	475 (76.5%)	576 (92.8%)	621
Total	9,645 (51.1%)	10,241 (54.2%)	14,090 (74.6%)	11,395 (60.3%)	18,889

SOURCE: Reference 1.

[a] Some LAUs apply more than one management method.

[b] High-rate application and low-rate application may not equal the subtotal because some States do not distinguish between high and low application rates.

Soil Type Requirements

Soil characteristics affect LAU siting because the conditions and properties of soil and sludge determine sludge application rates. Soil characteristics commonly considered include soil test information, permeability requirements, and special considerations for crop growth. No data were available concerning various soil types at LAUs.

Operation and Maintenance of Land Application Units

The operating and maintenance characteristics of an LAU consist of a wide spectrum of activities and precautions. This section is concerned with safety precautions and controls, employees and equipment, waste application techniques, waste application rate limits, and emergency preparedness. Limited data are available on current LAU practices in these areas. No data are available on contingency plans and LAU employees.

Safety Precautions and Controls

Data are presented in Table 4-77 for waste restrictions, application rate limits, and crop restrictions. The census data indicate that 54 percent of all LAUs employ waste restrictions, 75 percent have application rate limits, and 60 percent have restrictions on growing food-chain crops. The majority of facilities using these methods are municipal sewage sludge units.

Equipment

Equipment at LAUs is used for transportation, storage, and application of waste. The equipment used for waste transport and application varies according to the consistency of the waste applied (i.e., dewatered, liquid sludge, or wastewater). For dewatered sludge, open dump trucks are used for transporting, while bulldozers, loaders, graders, or box spreaders are used for spreading. Regular farm equipment is used for spreading or filling dewatered sludge, and heavy-duty disks or disk harrows are commonly used to bury the sludge.

Liquid sludge and wastewater are usually transported in tank trucks or pipelines (also used are closed railroad tanks and barges). Tank truck sprayers and spreaders with splash guards are used to apply the waste. Subsurface application is achieved by using subsurface injection dischargers mounted to plows or disks.

Storage facilities are used in cases of equipment breakdowns or adverse weather conditions, or to accommodate fluctuations in sludge production rates and agricultural cropping patterns. These storage facilities include lagoons, septic tanks, holding tanks, unconfined hoppers, and bins.[41]

Waste Application Techniques

Waste application techniques also vary with waste consistency. The application techniques for dewatered or liquid sludge differ from those for wastewater.

Municipal wastewater sludge can be applied to land in either liquid or dewatered form. Dewatered sludge application is similar to that of fertilizers, lime, or animal manure. Liquid sludge can be applied by tank truck, farm tank wagon, or subsurface injection. Land application of industrial wastewater is used for waste treatment and disposal. Surface application methods include sprinkler systems, ridge and furrow, border strip, and basin flooding. Land treatment methods include slow- and rapid-rate infiltration. The municipal sludge application rate may be determined by sludge composition, soil test information, fertilizer need of the crop grown, and annual waste addition limits. Fifty-nine (50 percent) of the 117 facilities in the food processing and pulp and paper LAU study used land spreading of solids, and 50 (42 percent) utilized slow-rate application. Data are presented in Table 4-78 for application techniques used by each industry type contacted.

Weeks in Operation

Approximately half the 117 facilities contacted for the food processing and pulp and paper LAU study operate year-round, while the other half operate less than 7 months per year. Figure 4-21 presents this data.

Emergency Preparedness

Emergency preparedness procedures used at LAUs include training personnel for emergencies, keeping emergency equipment on standby, using fire precaution procedures such as prohibition of unauthorized open burning, constructing storm-water channels to prevent flooding of potentially harmful wastewater, and using proper monitoring procedures (see the subsection on Environmental Monitoring at LAUs).

Table 4-78. APPLICATION TECHNIQUES FOR FOOD PROCESSING AND PULP AND PAPER LAND APPLICATION UNITS BY INDUSTRY TYPE

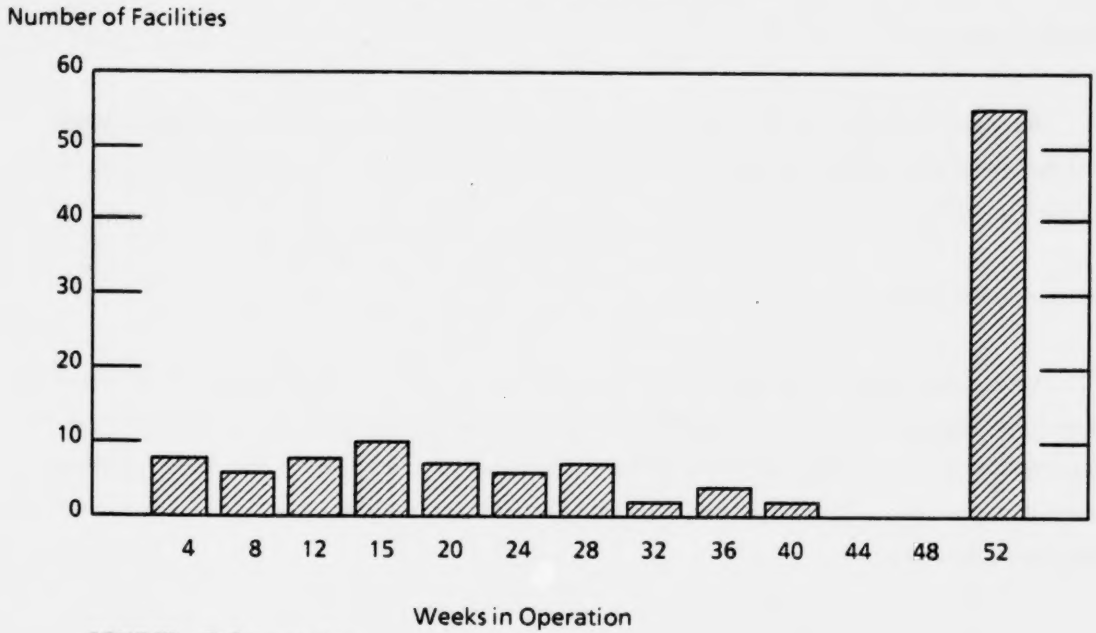
Industry Category	Application Technique				Total Land Application Units per Industry Category
	Slow Rate	Landspread	Overland Flow	Rapid Rate	
Pulp and paper	3	41	1	0	45
Meat	2	0	1	0	3
Dairy	2	3	0	0	5
Canned and Fresh Fruit and Vegetables	25	3	5	1	34
Bakery	1	0	0	0	1
Sugar	4	0	0	0	4
Beverages	3	5	0	0	8
Miscellaneous	10	7	2	0	19
Total[a]	50 (42%)	59 (49.6%)	9 (7%)	1 (0.8%)	119[b] (100%)

SOURCE: Reference 41.

[a] Percentages are rounded and do not total 100 percent.

[b] Facilities may use more than one technique.

Figure 4-21. WEEKS OF OPERATION PER YEAR FOR FOOD PROCESSING AND PULP AND PAPER INDUSTRIES



SOURCE: Reference 41.

Environmental Monitoring at Land Application Units

After sludge application, LAUs are monitored to determine the extent of environmental changes that have occurred as a result of waste application. Environmental monitoring needs vary according to land utilization (e.g., dedicated land disposal, agricultural purposes) and existing site characteristics. In general, monitoring at an LAU may include sampling and analysis of:

- sludge quantities and characteristics,
- soil characteristics (physical and chemical),
- ground-water quality beneath and adjacent to the site in the direction of ground-water flow,
- surface water run-off from the site,
- surface waters potentially affected by the site,
- odor, dust, and/or aerosol emissions from the site, and
- crops grown on the site.

Data from the Subtitle D census are presented in Table 4-79, showing the number of active Subtitle D LAUs with ground-water, surface water, air, or soil monitoring systems in place.

Forty-six percent of the 117 facilities contacted in the food processing and pulp and paper LAU study had ground-water monitoring systems. Twenty percent reported no monitoring, and 34 percent did not respond.[41]

Sludge System and Parameters

A sludge monitoring system is often used as a quality control tool and a warning of the presence of high concentrations of undesirable constituents. In addition, data on plant nutrients (nitrogen, phosphorus, and potassium) are sometimes monitored to assist sludge users (e.g., farmers, commercial tree growers) in efficient use of nutrients.

Table 4-79. NUMBER OF ACTIVE LAND APPLICATION UNITS WITH MONITORING SYSTEMS

Land Application Unit Type	Ground-Water Monitoring	Surface Water Monitoring	Air Monitoring	Soil Monitoring
Municipal Sewage Sludge at High Application Rate	43 (17.8%)	16 (6.6%)	0	206 (85.1%)
Municipal Sewage Sludge at Low Application Rate	170 (1.7%)	74 (0.8%)	0	4,157 (46.2%)
Total of Municipal Sewage Sludge[a]	337 (2.8%)	265 (2.2%)	100 (0.8%)	4,804 (40.2%)
Industrial Waste	592 (10.6%)	137 (2.4%)	31 (0.6%)	204 (3.6%)
Oil or Gas Waste	247 (34.0%)	230 (31.7%)	37 (5.1%)	42 (5.8%)
Other	3 (0.5%)	0	0	3 (0.5%)
Total	1,179 (6.2%)	632 (3.3%)	168 (0.9%)	5,053 (26.8%)

SOURCE: Reference 1.

[a] A high-rate application and low-rate application may not equal the subtotal because some States do not distinguish between high and low application rates.

The frequency of sludge sampling and analysis is commonly a function of system size, historical variations in sludge characteristics, the land application option being used, and the sampling frequency required by the appropriate regulatory agency.[44] Sludge may be analyzed for pH and a variety of chemical constituents. If the system used is potentially sensitive to pathogens and/or priority organics, these parameters may also be measured. No data were available on the numbers of facilities that monitor sludge or input wastes.

Soil System and Parameters

Periodic soil monitoring of an LAU may be done when the sludge contains significant quantities of heavy metals or priority-persistent organics, when heavy sludge application rates are used (e.g., as with a dedicated disposal site), when there is concern that the soil will become phytotoxic to vegetation on the site, or when the LAU's State or local permit requires certain periodic soil monitoring. Table 4-79 shows that about 27 percent of all LAUs identified in the census monitor the soil. Most of these are municipal sewage sludge LAUs.

Ground-Water System and Parameters

A detailed discussion of ground-water monitoring systems can be found in Section 4.1.3 (Landfills). The constituents analyzed from ground-water samples depend on monitoring goals, waste composition, uses of ground water, and regulatory requirements. The Subtitle D census indicated that about 6 percent of all LAUs monitor ground water (from Table 4-79). Most of these are industrial waste LAUs.

Surface Water Monitoring Systems and Parameters

Surface water monitoring is generally performed when it is required by an NPDES permit or when the site is near a sensitive surface water body.[43] Surface water monitoring parameters may include those that may either affect public health or contribute to eutrophication (e.g., nitrogen and phosphorus). Data from the census, presented in Table 4-79, indicate that about 3 percent of all LAUs monitor surface water. Municipal sewage sludge and oil and gas units monitor surface waters most frequently.

Air Monitoring Systems and Parameters

As shown in Table 4-79, few LAUs (less than 1 percent) monitor the air. No data were available on the monitoring systems or parameters used at the sites reporting air monitoring.

Crop Monitoring/Parameters

Vegetation monitoring is usually done when heavy sludge application rates are used (e.g., as with a dedicated disposal site) and there is concern that food-chain vegetation grown on the site may accumulate potentially harmful quantities of heavy metals (particularly cadmium) from the amended soil. It may also be performed to assure private farm owners that their crops are not being harmed by the use of sludge. The actual parameters monitored will vary among LAUs, depending on the sludge constituents of concern. No data on numbers of facilities that monitor crops were available.

4.3.3 ANALYSIS OF ENVIRONMENTAL IMPACTS AT LAUs

This subsection presents data relating to environmental impacts of Subtitle D LAUs and has the same objectives as Subsection 4.1.4. It presents the available aggregate and case-study information on the environmental impacts of contaminants in ground water, surface water, and air. No data on actual public health impacts of LAUs were available for this study. Table 4-80 presents Subtitle D census data relating to ground-water, surface water, and air impacts at Subtitle D LAUs. The table also presents statistics on State inspections and on the numbers of LAUs with monitoring systems.

Ground Water

As shown in Table 4-80, few LAUs monitor ground water. This table indicates that, in 1984, 17 municipal sewage sludge LAUs, 45 industrial LAUs, and 2 oil or gas and other LAUs were reported to have at least one ground-water protection standard violation. However, the number of reported violations is an imperfect measure of environmental impacts for reasons cited previously in the discussion of impacts at landfills (see Section 4.1.4).

Land treatment field studies were conducted for field application units to determine the environmental acceptability of LAU operations.[42] The conclusions of the case studies are site-specific, with each site possessing a unique balance of decomposition and waste migration, depending upon the various properties of the waste, site, and land cultivation techniques. These case studies are not reviewed here because their data were insufficient to draw general conclusions about health and environmental impacts at LAUs.

Surface Water

As shown in Table 4-80, few LAUs monitor surface water. The data in this table indicate that 17 municipal sewage sludge facilities; 60 industrial facilities, 25 oil or gas LAUs, and 24 other LAUs had at least one surface water contamination violation. No case studies providing significant information on surface water impacts from LAUs were available for this report.

Air

As shown in Table 4-80, few LAUs monitor air. This table indicates that 12 municipal sewage sludge facilities and 10 industrial LAUs were reported to have at least one air contamination violation in 1984. No case studies were available that provided information on air impacts associated with LAUs.

4.4 WASTE PILES

This section provides a general profile of Subtitle D waste piles. It also discusses the design and operation, and environmental impacts of waste piles. Waste piles have not yet been sufficiently characterized to determine the human health effects they cause.

Table 4-80. AGGREGATE DATA RELATING TO ENVIRONMENTAL CONTAMINATION AT LAND APPLICATION UNITS

	Number of Subtitle D Land Application Units, by Type						Total Land Application Units Per Category
	Municipal Sewage Sludge		Total of Municipal Sewage Sludge[a]	Industrial Waste	Oil or Gas Waste	Other	
	High Application Rate	Low Application Rate					
Total Active Facilities	242	9,779	11,937	5,605	726	621	18,889
Number of Facilities With at Least One Violation							
Ground-water contamination	4	13	17	45	2	2	66
Surface water contamination	1	15	17	60	25	24	126
Air contamination	0	12	12	10	0	0	22
State Inspection at Least Once Each Year[b]	18	1,267	2,321	796	652	26	3,795
Facilities With Monitoring							
Ground water	43	170	337	592	247	3	1,179
Surface water	16	74	265	137	230	0	632
Air emissions	0	0	100	31	37	0	168
Soil	206	4,517	4,804	204	42	3	5,053

SOURCE: Reference 1.

[a] High-rate application and low-rate application do not equal the total because some States do not distinguish between high and low application rates.

[b] These data include numbers cited by States or territories for inspection frequencies ranging from once a year to more than four times a year. The category excludes less frequent inspections and entries under the questionnaire category of "other."

4.4.1 GENERAL PROFILE

The Industrial Nonhazardous Waste Disposal Study[45] indicates that a number of industries use waste piles for either temporary stockpiling or permanent disposal of wastes. These industries include:

- fertilizer and other agricultural chemicals;
- electric power generation;
- industrial inorganic chemicals;
- industrial organic chemicals;
- lumber and wood products;
- pulp and paper;
- plastic and resin manufacturing;
- primary iron and steel manufacturing and ferrous foundries;
- primary nonferrous metals manufacturing and nonferrous foundries;
- stone, clay, glass, and concrete products; and
- textile manufacturing.

Waste piles were not included in the Subtitle D census, and sufficient data are not available to provide the numbers, locations, types, ownership characteristics, or sizes of all existing waste piles. Waste piles were, however, included in the Industrial Facilities Survey. Therefore, numbers for industrial waste piles are available. EPA is conducting ongoing studies to gather more information about this facility type.

Numbers of Waste Piles

Table 4-81 presents nationwide projections based on results from the Industrial Facilities Survey of the numbers of Subtitle D waste piles for the 17 major industries surveyed. The table also includes data on the number of industrial establishments with any active Subtitle D units, the number of establishments with active waste piles, the number of active waste piles, and the number of closed waste piles. The survey indicates that there are approximately 5,335 active industrial waste piles.

Table 4-81. NUMBER OF INDUSTRIAL ESTABLISHMENTS WITH SUBTITLE D WASTE PILES AND NUMBER OF WASTE PILES BY INDUSTRY TYPE

Industry Type	Number of Active Subtitle D Units[a]	Number of Active Waste Piles	Number of Establishments with Active Waste Piles	Number of Establishments with Closed Waste Piles
Organic Chemicals	385	79	37	36
Primary Iron and Steel	1,124	464	335	102
Fertilizer and Agricultural Chemicals	515	50	30	25
Electric Power Generation	1,528	110	98	18
Plastics and Resins Manufacturing	373	32	23	13
Inorganic Chemicals	1,281	98	60	42
Stone, Clay, Glass, and Concrete	7,247	2,528	2,082	305
Pulp and Paper	1,548	232	163	69
Primary Nonferrous Metals	880	312	261	93
Food and Kindred Products	8,029	540	340	141
Water Treatment	974	48	44	8
Petroleum Refining	1,249	158	136	43
Rubber and Miscellaneous Products	392	123	108	27
Transportation Equipment	723	362	307	93
Selected Chemicals and Allied Products	298	41	39	10
Textile Manufacturing	944	103	99	28
Leather and Leather Products	164	54	43	39
Total	27,654	5,335	4,205	1,092

SOURCE: Reference 2.

[a] These numbers correspond to the total universe of active Subtitle D units and include landfills, surface impoundments, land application units, and waste piles.

Waste Volume

Table 4-82 presents nationwide projections data from the Industrial Facilities Survey on the percentage of the total quantity of Subtitle D waste that waste piles receive. According to the survey, only 1.0 percent of the industrial waste stream disposed of in Subtitle D facilities is received by waste piles.

Table 4-83 shows the distribution of industrial establishments with waste piles according to the daily quantity of waste disposed of in their waste piles during 1985. The table displays nationwide projection data on 17 major industries.

Waste Pile Acreage

Limited information was available on the areal extent and volume of waste piles. These data were highly variable and industry-dependent, since many wastes are stockpiled only temporarily until they can be recycled. Waste pile acreage information from the Industrial Facilities Survey is presented in Table 4-84, which shows the distribution of industrial establishments with waste piles according to total waste pile acreage per establishment.

Waste Characteristics

Waste disposed of in Subtitle D waste piles is generally in slurry or solid form. Table 4-85 shows a partial list of the waste types disposed of in waste piles according to the Industrial Nonhazardous Waste Survey. The table illustrates the wide variety of compounds present in industrial waste piles. Additional data on the waste characteristics were discussed previously in Chapter 3.

Table 4-86 presents national projections from the Industrial Facilities Survey on the number of industrial establishments that store off-site waste and off-site household waste in their on-site waste piles. The survey indicates that about 5 percent of industrial waste piles accept off-site waste. Table 4-87 presents national projections from the survey on the number of industrial SQGs who dispose of their hazardous waste in on-site Subtitle D waste piles. According to the survey, very few establishments dispose of SQG hazardous waste in waste piles.

Table 4-82. WASTE QUANTITY DISPOSED OF IN INDUSTRIAL SUBTITLE D WASTE PILES IN 1985 BY INDUSTRY TYPE

Industry Type	Number of Establishments with Active Waste Piles	Waste Quantity Disposed of in Waste Piles (thousand tons)	Total Waste Quantity Disposed of in All Facilities (thousand tons)	Percent of Total Waste Disposed of in Waste Piles
Organic Chemicals	37	48	58,864	0.08
Primary Iron and Steel	335	6,129	1,300,541	0.5
Fertilizer and Agricultural Chemicals	30	4,820	165,623	2.9
Electric Power Generation	98	832	1,092,277	0.08
Plastics and Resins Manufacturing	23	3,018	180,510	1.7
Inorganic Chemicals	60	41,323	919,725	4.5
Stone, Clay, Glass, and Concrete	2,082	9,184	621,974	1.5
Pulp and Paper	163	1,469	2,251,700	0.07
Primary Nonferrous Metals	261	8,764	67,070	13
Food and Kindred Products	340	460	373,517	0.1
Water Treatment	44	9	58,846	0.1
Petroleum Refining	136	79	168,632	0.05
Rubber and Miscellaneous Products	108	58	24,198	0.2
Transportation Equipment	307	708	12,669	4.6
Selected Chemicals and Allied Products	39	8	62,987	0.01
Textile Manufacturing	99	18	253,780	<0.01
Leather and Leather Products	43	11	3,235	0.3
Total[a]	4,205	76,936	7,616,149	1.0

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

Table 4-83. NUMBER OF ESTABLISHMENTS WITH WASTE PILES BY INDUSTRY TYPE AND WASTE QUANTITY DISPOSED OF IN THEM IN 1985

Industry Type	Number of Establishments According to Amount of Waste Disposed of in Them (thousand tons)						Total Establishments Per Industry Type[a]
	Less than 0.5	0.5-5	5.1-20	21-100	101-1,000	More than 1,000	
Organic Chemicals	21	15	2	0	0	0	37
Primary Iron and Steel	202	74	24	14	2	2	317
Fertilizer and Agricultural Chemicals	19	2	4	1	3	1	30
Electric Power Generation	77	8	0	8	1	0	93
Plastics and Resins Manufacturing	19	1	2	0	0	1	23
Inorganic Chemicals	30	12	4	2	7	4	60
Stone, Clay, Glass, and Concrete	1,549	184	131	57	21	0	1,942
Pulp and Paper	51	63	38	7	2	0	162
Primary Nonferrous Metals	198	41	14	4	3	1	261
Food and Kindred Products	297	28	4	11	0	0	340
Water Treatment	41	1	0	0	0	0	42
Petroleum Refining	112	21	2	0	0	0	135
Rubber and Miscellaneous Products	76	21	1	0	0	0	98
Transportation Equipment	213	70	15	2	1	0	300
Selected Chemicals and Allied Products	33	6	0	0	0	0	39
Textile Manufacturing	90	10	0	0	0	0	99
Leather and Leather Products	37	3	0	0	0	0	39
Total[a]	3,064	558	242	106	40	9	4,019[b]

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

[b] Overall response rate for this table is 95.6 percent.

Table 4-84. NUMBER OF ACTIVE INDUSTRIAL SUBTITLE D ESTABLISHMENTS WITH WASTE PILES BY INDUSTRY TYPE AND TOTAL AREA OF WASTE PILES IN EACH ESTABLISHMENT

Industry Type	Number of Establishments with Waste Piles According to Size					Total Establishments Per Industry Type[a]
	Less than 5 Acres	5 - 10 Acres	11 - 50 Acres	51 - 100 Acres	More than 100 Acres	
Organic Chemicals	35	0	0	0	1	36
Primary Iron and Steel	311	16	5	1	1	334
Fertilizer and Agricultural Chemicals	22	2	2	0	4	30
Electric Power Generation	91	5	1	1	0	98
Plastics and Resins Manufacturing	20	0	0	0	1	21
Inorganic Chemicals	44	2	6	1	7	60
Stone, Clay, Glass, and Concrete	2,017	29	5	12	0	2,063
Pulp and Paper	148	6	7	1	0	163
Primary Nonferrous Metals	243	9	2	1	6	261
Food and Kindred Products	315	13	12	0	0	340
Water Treatment	44	0	0	0	0	44
Petroleum Refining	131	4	1	0	0	136
Rubber and Miscellaneous Products	108	0	0	0	0	108
Transportation Equipment	304	2	1	0	0	307
Selected Chemicals and Allied Products	39	0	0	0	0	39
Textile Manufacturing	68	1	0	0	31	99
Leather and Leather Products	43	0	0	0	0	43
Total[a]	3,983	89	42	17	51	4,183[b]

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

[b] Overall response rate for this table is 99.5 percent.

Table 4-85. WASTE TYPES DISPOSED OF IN WASTE PILES

Industry	Waste Types
Fertilizer and other agricultural chemicals (SIC 2873-2879)	Waste gypsum
Electric power generation (SIC 4911)	Coal piles Fly ash Bottom ash/slag
Industrial inorganic chemicals (SIC 2812-2819)	
Hydrofluoric acid	Gypsum
Calcium carbide	Lime
Phosphorus	Slag
Industrial organic chemicals (SIC 2819)	Precipitates/filtration residues Sludges Heavy ends Off-spec. products Spent adsorbent Spent catalyst
Lumber and wood products (SIC 24)	Wood residues
Pulp and paper (SIC 26)	Papermill sludges Pulping rejects and fines Bark wastes
Plastic and resin manufacturing (SIC 2821)	Off-specification products and sludges Decantates/filtrates Miscellaneous solids Spent solvents Heavy ends Light ends Spent carbon Sludges
Primary iron and steel manufacturing and ferrous foundries (SIC 3312-3321)	Steelmaking slag Blast furnace slag Blast furnace sludge Spent pickle liquor (dumped on slag piles) Continuous casting scale Primary mill scale Hot rolling scale Fly/bottom ash Electric arc furnace slag

Table 4-85. (continued)

Industry	Waste Types
Primary nonferrous metals manufacturing and nonferrous foundries (SIC 3330-3399)	
Aluminum	Butt screenings Electromelt furnace slag Dross Spent potliners Shot blast dusts
Copper	Slag Slurries and sludges (with slag)
Zinc	Dried polishing pond solids Goethite leach residues Saleable zinc-lean residues Zinc-oxide clinker Refractory brick
Lead	Slag Acid plant blowdown/run-off/washdowns Treated slag granulation water dredged solids Sediment from granulation water slag Waste brick
Stone, clay, glass, and concrete products (SIC 32)	Kiln dusts
Textile manufacturing (SIC 22)	Not available

SOURCE: Reference 45.

Table 4-86. NUMBER OF INDUSTRIAL ESTABLISHMENTS WITH SUBTITLE D WASTE PILES RECEIVING OFF-SITE WASTE AND OFF-SITE HOUSEHOLD WASTE BY INDUSTRY TYPE

Industry Type	Number of Establishments with Active Waste Piles	Number Accepting Off-site Waste	Number Accepting Off-site Household Waste
Organic Chemicals	37	11	0
Primary Iron and Steel	335	5	0
Fertilizer and Agricultural Chemicals	30	4	0
Electric Power Generation	98	32	23
Plastics and Resins Manufacturing	23	0	0
Inorganic Chemicals	60	4	1
Stone, Clay, Glass, and Concrete	2,082	79	69
Pulp and Paper	163	3	0
Primary Nonferrous Metals	261	7	0
Food and Kindred Products	340	30	0
Water Treatment	44	5	1
Petroleum Refining	136	30	0
Rubber and Miscellaneous Products	108	1	0
Transportation Equipment	307	14	7
Selected Chemicals and Allied Products	39	2	2
Textile Manufacturing	99	0	0
Leather and Leather Products	43	1	0
Total	4,205	228	103

SOURCE: Reference 2.

Table 4-87. NUMBER OF SMALL-QUANTITY-GENERATOR INDUSTRIAL ESTABLISHMENTS THAT DISPOSE OF THEIR SMALL-QUANTITY-GENERATOR WASTE IN THEIR WASTE PILES BY INDUSTRY TYPE

Industry Type	Number of Establishments with Active Waste Piles	Number with Waste Piles That Are SQGs	Number of SQG Establishments Disposing of SQG Waste in Their Waste Piles
Organic Chemicals	37	0	0
Primary Iron and Steel	335	118	5
Fertilizer and Agricultural Chemicals	30	7	0
Electric Power Generation	98	61	5
Plastics and Resins Manufacturing	23	2	0
Inorganic Chemicals	60	14	0
Stone, Clay, Glass, and Concrete	2,082	552	62
Pulp and Paper	163	62	1
Primary Nonferrous Metals	261	88	4
Food and Kindred Products	340	188	11
Water Treatment	44	38	0
Petroleum Refining	136	46	1
Rubber and Miscellaneous Products	108	33	10
Transportation Equipment	307	38	14
Selected Chemicals and Allied Products	39	24	22
Textile Manufacturing	99	11	0
Leather and Leather Products	43	3	0
Total[a]	4,205	1,285	135

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding.

4.4.2 DESIGN AND OPERATION OF WASTE PILES

This section discusses the design, and the operation and maintenance of Subtitle D waste piles. No information was available to ascertain the extent of ground-water, surface water, or air monitoring in the vicinity of Subtitle D waste piles.

Waste Pile Design

Waste piles are often used for temporary storage of wastes that will be recycled or used as fuel. Therefore, little design is involved in the construction of waste piles. Some waste pile areas have run-on/run-off controls to minimize the leaching of contaminants from the wastes. In a few States, run-off impoundments or catch basins have been required to protect surface waters. Liner systems to control the release of contaminants to ground water are generally not used.

Waste Pile Operation and Maintenance

Most (55 percent) of the establishments with waste piles eventually send their wastes off site. Table 4-88 presents results from the Industrial Facilities Survey on the number of industrial establishments with waste piles and the various management methods by which the materials are handled after they are placed in the waste piles. No other data were available concerning the operation and maintenance of Subtitle D waste piles.

4.5 SUMMARY

Chapter 4 provides data on the numbers, design and operating features, leachate and gas characteristics, and the monitoring systems in place at Subtitle D facilities. These data, along with the waste characterization data from Chapter 3, provide the information necessary to determine if Subtitle D wastes and facilities are causing significant impacts to human health and the environment. (See Volume I of this report.)

The census identified 16,416 active Subtitle D landfills in the United States. Municipal waste landfills, industrial waste landfills, and demolition debris landfills comprise the largest landfill subcategories, making up 57 percent, 21 percent, and 16 percent of the landfill universe, respectively. Seventy-two percent of all landfills receive less than 30,000 cubic yards per year (30 tons per day).

Table 4-88. MANAGEMENT METHODS FOR WASTE STORED IN INDUSTRIAL SUBTITLE D WASTE PILES BY INDUSTRY TYPE

Industry Type	Number of Establishments with Active Waste Piles	Waste Quantity Placed in Waste Piles (thousand tons in 1985)	Number of Establishments per Management Method								
			Sent Off-site	Recycled On-site	Incinerated On-site	Transferred to Landfill On-site	Transferred to Land Application Units On-site	Transferred to Surface Impoundments On-site	Kept in Permanent Storage in Waste Pile	Other	No Management Method
Organic Chemicals	37	48	29	11	1	1	1	0	3	7	0
Primary Iron and Steel	335	6,129	238	45	7	8	3	0	24	59	0
Fertilizer and Agricultural Chemicals	30	4,820	7	4	2	0	1	0	10	12	0
Electric Power Generation	98	832	43	24	0	3	0	1	30	32	0
Plastics and Resins Manufacturing	23	3,018	10	2	1	9	0	0	2	2	0
Inorganic Chemicals	60	41,323	35	8	1	2	1	0	20	8	1
Stone, Clay, Glass, and Concrete	2,082	9,184	1,174	305	9	55	39	9	423	391	1
Pulp and Paper	163	1,469	103	2	7	4	0	1	8	49	0
Primary Nonferrous Metals	261	8,764	171	84	0	11	1	0	53	47	0
Food and Kindred Products	340	460	124	44	3	30	105	0	25	85	0
Water Treatment	44	9	37	2	2	1	0	0	1	3	0
Petroleum Refining	136	79	65	8	3	1	0	0	35	19	1
Rubber and Miscellaneous Products	108	58	106	1	11	0	0	0	0	2	0
Transportation Equipment	307	708	234	16	1	3	7	1	10	99	0
Selected Chemicals and Allied Products	39	8	33	2	0	0	0	0	2	4	0
Textile Manufacturing	99	18	87	0	0	1	0	1	2	10	0
Leather and Leather Products	43	11	37	1	1	0	0	0	0	4	0
Total[a]	4,205	76,936	2,533	558	50	129	158	13	648	835	3

SOURCE: Reference 2.

[a] These are the correct totals. The table entries may not add to their respective totals because of rounding

Leachate and gas from landfills contain a variety of organic and inorganic compounds. These substances are found at a wide range of concentrations. The current data have many limitations.

Design and operation practices employed at Subtitle D landfills include synthetic and natural liners, leachate collection systems, run-on/run-off controls, methane controls, leachate treatment and recirculation, liquid waste restrictions, and environmental monitoring. Less than half of all Subtitle D landfills employ any one of these environmental controls.

Releases to all environmental media were observed to occur at Subtitle D landfills. Factors observed to contribute to ground-water contamination include age of landfill, depth to ground water, soil and liner permeability, net infiltration rate, and ground-water flow rate and characteristics of waste received.

The Subtitle D census identified 191,822 surface impoundments (SIs) in the United States. Oil and gas SIs constitute 65 percent of the Subtitle D SI universe, and mining waste SIs, agricultural waste SIs, and industrial waste SIs constitute 10 percent, 9 percent, and 8 percent of the universe, respectively. Eighty-two percent of all SIs receive 50,000 or fewer gallons per day.

Design and operation practices employed at Subtitle D SIs include synthetic and natural liners, leak detection systems, overtopping controls, waste restrictions, discharge permits, and environmental monitoring. Less than one-third of all Subtitle D SIs employ any one of these controls. Releases to all environmental media have been observed at Subtitle D SIs.

The Subtitle D census identified 18,889 land application units (LAUs) in the United States. Municipal sewage sludge LAUs compose 63 percent of the universe, and industrial and oil or gas LAUs make up 30 percent and 4 percent of the LAU universe, respectively. Seventy percent of all LAUs receive less than 50 tons of waste per year (dry weight).

Design and operation practices employed at Subtitle D LAUs include run-on/run-off controls, waste restrictions, application rate limits, restrictions on the growing of food-chain crops, and environmental monitoring. Seventy-five percent of all LAUs limit waste application rates, and more than half use run-on/run-off controls, waste restrictions, and restrictions on the growing of food-chain crops. Releases to all environmental media have been observed at Subtitle D LAUs.

The Industrial Facilities Survey indicates that there are approximately 5,335 active industrial waste piles. Available information indicates that a number of industries use waste piles for either temporary stockpiling or permanent disposal of Subtitle D wastes. No data on environmental monitoring at waste piles on releases to the environment were available.

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Chapter 5

CHARACTERIZATION OF STATE SUBTITLE D PROGRAMS

This chapter discusses the quality of the data used for characterizing the State Subtitle D programs. It provides an overview of State Subtitle D programs, focusing on organization, resources, the types and numbers of solid waste management facilities, permit or other approval mechanisms, and enforcement activities. Finally, the chapter reviews State regulations specific to four types of Subtitle D facilities: landfills, surface impoundments (SIs), land application units (LAUs), and waste piles.

5.1 QUALITY OF DATA FOR STATE PROGRAM CHARACTERIZATION

The primary sources of State program data used in this assessment are the Subtitle D census,[1] the regulations reviews,[2] the Review of State Enforcement Powers and Authorities Under Subtitle D of RCRA,[3] and the State Regulatory Equivalency Analysis.[4] These reports represent the most recent and most comprehensive State Subtitle D data collection efforts.

One significant problem with respect to most of the estimates presented in the Subtitle D census is nonresponse to survey questions. This factor results in underestimates for many of the totals presented in this assessment. To verify the quality of the data obtained, EPA asked respondents to indicate whether they felt that the quality of their responses was good, fair, poor, or very poor. Data quality concerns are noted in this chapter where pertinent.

5.2 OVERVIEW OF STATE SUBTITLE D PROGRAMS

5.2.1 PROGRAM ORGANIZATION AND MANAGEMENT

As described previously in the report, Subtitle D of RCRA established a program for solid waste management to be implemented by the States through comprehensive planning pursuant to Federal criteria. One unclear area of responsibility, however, is implementation of the program on Indian lands. Under Section 1004 of RCRA, Indian Tribes, authorized Tribal organizations, and Alaska Native Villages are included in the definition of municipality. While a municipality plans and implements its own solid waste management program, it is subject to State solid waste regulations and State solid waste management objectives. However, States generally do not have jurisdiction over Indians in Indian country unless Congress has clearly expressed an intention to permit it.[5] The approach to implementation of the criteria on Indian lands needs clarification. Agency recommendations for addressing this problem are presented in Volume I.

The specific State Subtitle D program elements that make up organization and management are State organization; budgetary and personnel resources; the qualifications and training of the personnel; and the overall program strategy. The available program data are analyzed according to these elements.

State Organization

The Subtitle D census asked each State and territory to list all agencies responsible for developing, regulating, enforcing, overseeing, and otherwise administering any part of the Subtitle D program. Fifteen States and territories indicated that they have one agency with administrative authority for Subtitle D activities. The remaining 39 respondents indicated that from two to eight different agencies administer parts of the Subtitle D program. The most frequently listed were solid waste and water-related agencies. Some of the other agencies reported to be involved in administering programs for specific Subtitle D facility types include oil and gas commissions, mining and reclamation bureaus, and air compliance offices.

Subtitle D programs for landfills were most frequently reported to be administered by solid waste agencies; programs for SIs, on the other hand, were most frequently reported to be administered by water agencies. Subtitle D land application programs are usually administered by either a solid waste or a water agency.

Although the response rate on State administrative organization was high in the Subtitle D census, it is likely that not all agencies involved in Subtitle D activities are represented. With the exception of solid waste agencies, other State agency activities are not generally perceived to be related to Subtitle D programs. Many water agencies, for example, do not view their activities as being related to the implementation of Subtitle D, despite the fact that some of their work involves direct enforcement efforts at Subtitle D facilities (e.g., SIs).

Further complicating the organization data is the fact that few agencies are perceived as having a unique budget for Subtitle D activities, even though they may spend money on Subtitle D work (e.g., inspecting municipal solid waste landfills). In some cases it appears that money is redirected from other agency programs to offset the lack of money for Subtitle D programs. Furthermore, the list of agencies may not account for State regional or district offices, even where State organizational structures are such that these offices may be heavily involved in Subtitle D inspection and enforcement activities.

Overall, few States and territories administer their solid waste management programs in the Federal mold, using one agency or department to handle all Subtitle D activities. Most, in fact, have at least two separate agencies, generally a solid waste and a water agency, that carry out Subtitle D functions.

Resources, Staff Qualifications and Training, Program Strategy

The Subtitle D census provides the following types of data: estimates of total dollars spent, sources of funding, total person-hours expended, types of program activities undertaken, and priorities for different Subtitle D program activities. Although these data do not present a complete picture of State programs, they do indicate the level of effort that States and territories currently commit to Subtitle D activities.

Of the 141 agencies that responded, 104 included the portion of their overall budget that was spent on Subtitle D activities. The total dollar amount reported for these agencies nationwide was $39,282,455 in fiscal year 1984 (FY84). The average number of dollars reported per State or territory was $785,649. Water agency expenditures were larger on average ($631,389 per State or territory) than solid waste agency expenditures ($427,184 per State or territory). The majority of the States and territories (28) budgeted less than $500,000 on Subtitle D activities. A sizable number (13) allocated between $500,000 and $1,000,000. A few States and territories (7) spent more than $1,000,000 for Subtitle D programs.

The total dollar amount reported is probably an underestimate of the amount spent on Subtitle D activities nationwide. As noted above, some agencies with Subtitle D responsibilities failed to provide an estimate of the amount spent on Subtitle D activities, and even among those providing estimates, the figures are admittedly very rough.

The Subtitle D census also asked each State to provide an estimate of the percentage of its total Subtitle D budget for FY84 and FY85 that came from State sources, Federal sources, license or user fees, and other funding sources. These estimates are presented in Table 5-1. The census found that in FY84, 84.6 percent of all Subtitle D funding was attributed to State sources and that only 7.5 percent of such funding came from Federal sources. Federal funding for Subtitle D activities came almost exclusively through water agencies. The National Solid Waste Survey[6] results for FY84 roughly parallel those of the Subtitle D census, with an average of 89 percent of all Subtitle D funding coming from State sources and 3.5 percent coming from Federal sources.

Table 5-1. SOURCES OF SUBTITLE D FUNDING

Funding Source	Percentage of Funding per Source[a]	
	Fiscal year Ending in 1984	Fiscal Year Ending in 1985
State sources	84.6	85.1
Federal sources	7.5	7.1
License or user fees	3.5	6.0
Other	4.4	1.9

SOURCE: Reference 1.

[a] Percentages are rounded and may not total 100 percent.

In contrast, data for FY81 reported by the National Solid Waste Survey show that 58 percent of the funding for Subtitle D activities came from State sources, and 30 percent was provided by Federal sources. The census data reveal the marked change in the balance of State and Federal funding for Subtitle D programs since 1981. In addition to State and Federal sources, the Subtitle D census reports that in FY84 and FY85, nine and ten States, respectively, used license or user fees and other funding sources to account for 7.9 percent of the aggregate funding in those years.

Estimates of the total number of person-hours expended on Subtitle D activities in FY84 were reported for 103 of the 141 agencies identified by the States and territories as being involved in Subtitle D activities. A total of 1,715,539 hours was reported by the respondents (although this number is probably an underestimate for the reasons cited earlier). Using 2,000 hours as a rough measure of person-hours per year, this number represents a total of 858 person-years committed to Subtitle D functions by the States and territories. As with the Subtitle D budget estimates discussed above, these work-year estimates vary widely among the States and territories. Twenty-two States and territories allocate 10 or fewer person-years to Subtitle D, 15 devote between 10 and 25, and 10 commit 25 or more person-years.

The Subtitle D census also reports estimates of the percentage of total hours expended in performing seven different Subtitle D program activities (see Table 5-2.) The two types of activities most frequently pursued were surveillance/enforcement and permitting/licensing. These accounted for almost 70 percent of all hours expended on Subtitle D activities. Training and research had the smallest percentages of hours devoted to them, with less than 5 percent between them.

As an indication of additional needs, the census asked each State and territory to rank the seven activities listed in Table 5-2 with respect to their potential for improving Subtitle D program effectiveness, assuming additional resources were available. The overall and facility-specific activity rankings are shown in Table 5-3. Surveillance and enforcement activities ranked highest overall for each of the three facility types. This indicates that the States and territories perceive that their Subtitle D program effectiveness would be improved most by further expanding the activity that is now most frequently pursued -- surveillance and enforcement. The small percentage of hours devoted to training and the low ranking in importance indicate that States and territories do not place great emphasis on training in their Subtitle D programs. The data are less conclusive regarding overall program strategy, but they strongly suggest that States and territories have recognized priorities should additional funding become available.

5.2.2 IDENTIFICATION AND STATUS OF SUBTITLE D FACILITIES

The specific program elements that make up identification/status are an active solid waste facility and practice identification effort, an accurate data base on facilities, and an up-to-date status determination for all facilities. The available program data are analyzed according to these program elements.

Identification Effort

The Subtitle D census contains no data on the efforts that State and territorial programs make in identifying the universe of Subtitle D facilities and in ensuring that they are in the regulatory system. The best indications of State efforts in this respect are the data bases they have developed on facilities and the confidence States indicate that they have in the data.

Table 5-2. STATE SUBTITLE D ACTIVITIES

Subtitle D Activity	Percent of Hours	Number of States Reporting
Surveillance and enforcement	41.1	46
Permitting and licensing	27.8	46
Technical assistance	9.1	46
Planning	5.8	42
Regulation development	4.5	40
Training given	2.8	30
Research	1.5	16

SOURCE: Reference 1.

Table 5-3. IMPORTANCE OF SUBTITLE D PROGRAM ACTIVITIES AS RANKED BY THE STATES

Overall Ranking	Subtitle D Activity	Importance According to Facility Type		
		Landfill Ranking	Surface Impoundment Ranking	Land Application Unit Ranking
1	Surveillance and enforcement	1	1	1
2	Technical assistance	2	2	3
3	Permitting or licensing	3	4	2
4	Regulation development	5	3	4
5	Training	6	5	5
6	Planning	4	6	6
7	Research	7	7	7

SOURCE: Reference 1.

Data on Facilities

The census collected State and territorial data on three of the four basic types of land disposal facilities regulated under Subtitle D: landfills, SIs, and LAUs. Chapter 4 of this report presents the data States have available on the numbers of such facilities and discusses State indications of the quality of such data.

The available State and territorial data on Subtitle D facilities suggest that the total universe is approximately 227,000 Subtitle D units, although this number is likely to be an underestimate. The Subtitle D census indicates that the States and territories do not have consistent approaches for identifying and maintaining data on Subtitle D facilities and thus have data of varying degrees of accuracy for the different facilities regulated by Subtitle D.

Status Determination

The basis for determining the status of a facility or practice are the Federal criteria in 40 CFR Part 257 promulgated by EPA in 1979 for distinguishing a sanitary landfill from an open dump. The Subtitle D census does not include data (other than inspection data discussed below in enforcement) on State and territorial efforts at determining the regulatory status of facilities based on the 40 CFR Part 257 criteria. The Inventory of Open Dumps,[7] however, provides a limited record of State evaluations of Subtitle D facilities. It lists facilities that States have found to be in violation of the 40 CFR Part 257 criteria, and that thereby pose a reasonable probability of adverse effects on human health or the environment. Also included in the inventory are brief State descriptions of actions and approaches taken in evaluating the universe of facilities.

The inventory represents an incomplete record of status determinations for Subtitle D facilities, however, because State participation in the inventory has been extremely limited in recent years due to the termination of Federal Subtitle D funding. For example, the most recent installment of the inventory, published in June 1985, received new information from only 16 States. Table 5-4 presents data from this inventory on the number of open dumps reported by the States and territories.

It cannot be assumed that, because the States and territories did not participate in the inventory, actions were not being taken to close open dumps. Solid waste management laws in a number of States and territories have specific bans on open dumping. Further bans on open dumps

Table 5-4. NUMBER OF OPEN DUMPS IN THE 1985 INVENTORY

State	Number of Dumps	State	Number of Dumps
Alabama	12	New Mexico	5
Alaska	50	New York	55
Arizona	39	North Carolina	0
Arkansas	26	North Dakota	8
California	35	Ohio	50
Colorado	11	Oklahoma	61
Connecticut	30	Oregon	20
Delaware	1	Pennsylvania	48
Florida	37	Rhode Island	6
Georgia	11	South Carolina	3
Hawaii	1	South Dakota	64
Idaho	39	Tennessee	6
Illinois	12	Texas	11
Indiana	12	Utah	31
Iowa	3	Vermont	9
Kansas	3	Virginia	1
Kentucky	9	Washington	32
Louisiana	338	West Virginia	45
Maine	16	Wisconsin	51
Maryland	6	Wyoming	17
Massachusetts	61	American Samoa	5
Michigan	151	Guam	1
Minnesota	66	Northern Mariana Islands	3
Mississippi	88	Puerto Rico	64
Missouri	3	Virgin Islands	5
Montana	42	Total	1,789
Nebraska	1		
Nevada	52		
New Hampshire	28		
New Jersey	5		

SOURCE: Reference 7.

are implicit in permit or license provisions, which typically prohibit the disposal of solid waste in unpermitted facilities. All of the States and territories have permit or license requirements for certain types of Subtitle D facilities in their solid waste management laws.[3]

5.2.3 REGULATIONS AND PERMITS

As a part of the State solid waste management planning process described in 40 CFR Part 256, States are to have provided for the establishment of regulatory powers that accomplish the following objectives:

- development of standards equivalent to or more stringent than the EPA classification criteria at 40 CFR Part 257;
- development of surveillance capabilities to detect adverse environmental effects;
- development of a permitting program; and
- creation of administrative and judicial enforcement capabilities.

This section discusses the results of the State Regulatory-Equivalency Analysis[4] (SREA) for accomplishing the first objective and the findings of the census for accomplishing the second and third objectives. Progress in the establishment of enforcement authorities is discussed in Subsection 5.2.4.

State Regulatory Equivalency Analysis

The SREA was conducted to determine the adoption rate by States of 40 CFR Part 257 Criteria for Classification of Solid Waste Disposal Facilities and Practices on a criterion-by-criterion basis.[4] Because of the broad performance-based standards of the EPA criteria, the evaluation guidelines were designed to gauge equivalency in the overall environmental effect, rather than duplication of regulatory language. A two-category classification scheme was developed, and States were determined to be either "comparable" or "noncomparable" in the level of protection of human health and the environment afforded by each of the criteria specified in Part 257. The EPA criteria address:

- floodplain integrity and management;

- endangered species preservation;
- surface water protection;
- ground-water protection;
- application of wastes to land used for the production of food-chain crops;
- disease prevention;
- air quality protection; and
- public safety with respect to explosive gases, fires, bird hazards to aircraft, and site accessibility.

Section 256.21 Requirements for State Regulatory Powers provides that States must have adequate powers to enforce solid waste disposal standards that are equivalent to or more stringent than the 40 CFR Part 257 criteria. Table 5-5 presents the adoption rate of the performance standards in 40 CFR Part 257. Only State solid waste regulations were examined for this analysis, and no effort was made to evaluate the adequacy or effectiveness of State solid waste programs (i.e., only regulations were examined). Results of the SREA clearly indicate that very few States have adopted the Federal criteria. A higher adoption rate had been anticipated, since 25 States and territories have approved 40 CFR Part 256 State Solid Waste Management Plans.

Table 5-5. 40 CFR PART 257 ADOPTION BY STATES AND TERRITORIES AND THE DISTRICT OF COLUMBIA

Criteria	Adoption (percent)
Floodplains	41
Endangered species	29
Surface water	57
Ground water	68
Land application	14
Disease	34
Air	68
Safety	30

SOURCE: Reference 4.

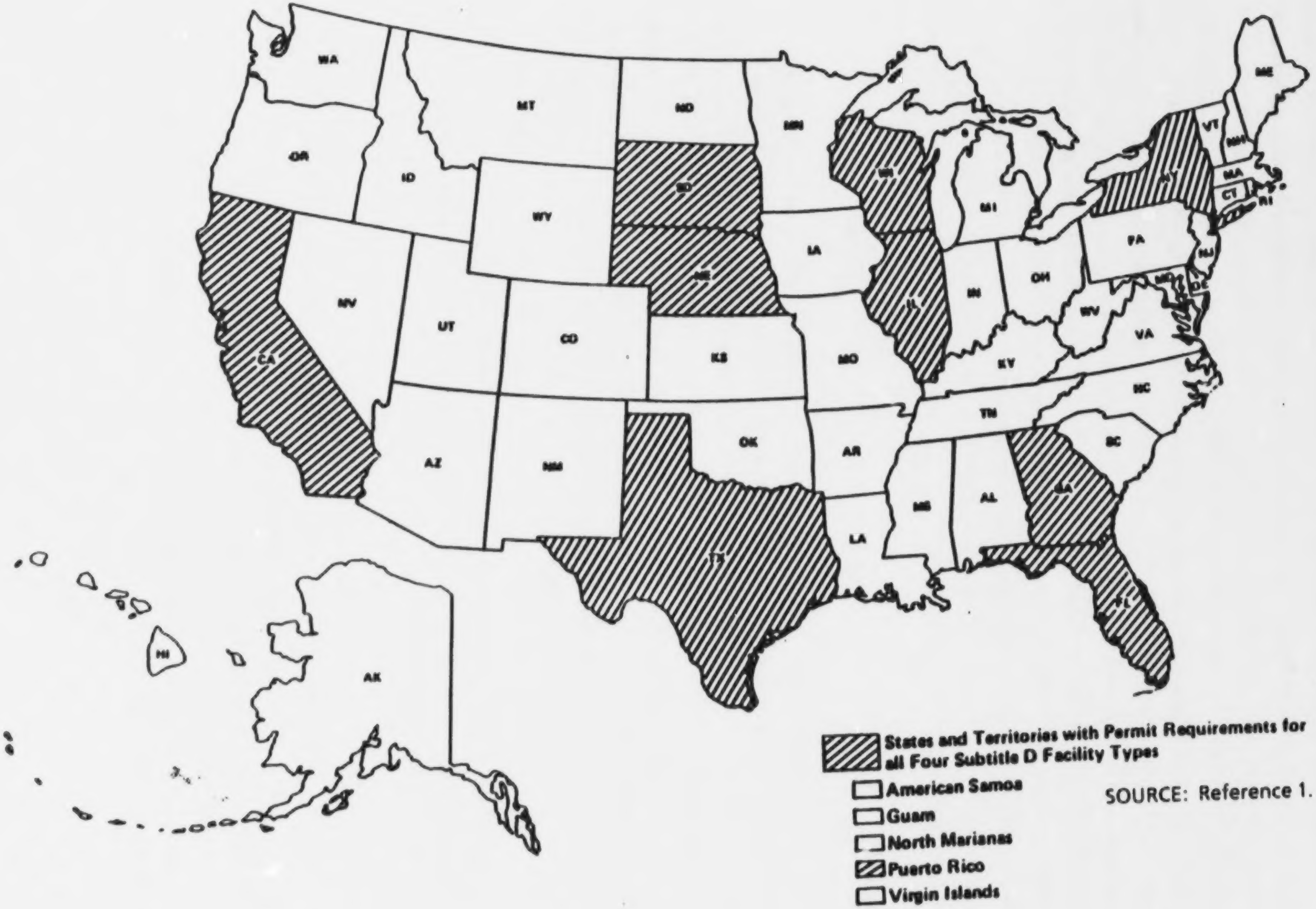
There are several possible explanations why the SREA found a lower adoption rate of 40 CFR Part 257 by States and territories. First, many 40 CFR Part 256 State solid waste management plans were approved in 1980 and 1981 with compliance schedules that required States and territories to revise their regulations to be consistent with 40 CFR Part 257 as soon as State regulatory approval boards, commissions, and agencies could satisfy State regulatory amendment requirements. Some of these schedules may not have been implemented. Second, the States and territories have amended their solid waste management regulations numerous times so that regulations that may have been equivalent to or more stringent than 40 CFR Part 257 in 1981 may now be viewed as less stringent. Finally, the State plan review process is an iterative process, while the SREA was a desk-top study. During State plan reviews, other State regulations that play a role in overall solid waste management programs are considered (i.e., water and air regulations), while the SREA only considered State solid waste regulations.

Permits

The Subtitle D census and regulations reviews contain data on the number of States and territories that have permit or plan approval requirements for Subtitle D facilities. Figure 5-1 presents a map of the United States depicting the States and territories that have such requirements. While all States and territories have permit requirements for certain types of Subtitle D facilities, only ten report having permit, license, or plan approval mechanisms for landfills, SIs, LAUs, and waste piles. Although most States and territories have permit requirements for landfills (50) and waste piles (29), fewer have requirements for SIs (16) and LAUs (27). The breakdown by facility type is discussed in Section 5.3 of this chapter.

The census also solicited information about permit fee requirements. Fifty-one percent of the States and territories responding had permit fees for landfills, 40 percent had fees for SIs, and 46 percent had permit fees for LAUs.

The Subtitle D census contains data on the number of Subtitle D facilities (excluding waste piles) that have permits or approved facility plans. Table 5-6 presents these data relative to the total universe of Subtitle D facilities. Those facilities that have "licenses" are not included here because, in most cases, a license does not require prior submission of a formal plan. A further breakdown by facility type of the number of permits and percentage permitted is contained in Section 5.3. The data indicate that while the number of permits granted to Subtitle D facilities is high, almost half of the facilities remain unpermitted.



SOURCE: Reference 1.

Figure 5-1. STATES AND TERRITORIES THAT HAVE PERMIT REQUIREMENTS FOR ALL SUBTITLE D

Table 5-6. NUMBER OF SUBTITLE D FACILITIES WITH PERMITS

Facility Type[a]	Number	Percent of Total
Landfills	8,422	51.3
Surface impoundments	95,478	49.8
Land application units	12,502	66.2
Total	116,402	51.2

SOURCE: Reference 1.

[a] Data were not available on waste piles.

5.2.4 ENFORCEMENT AUTHORITIES

State solid waste enforcement authorities fall into two general categories: administrative and judicial. Administrative enforcement actions include: issuing, modifying, suspending, and revoking permits, licenses, and registrations; conducting inspections or surveys; and issuing various types of compliance and enforcement orders. Prohibiting open dumps and directly cleaning up waste sites are also administrative enforcement actions.

After administrative procedures have been exhausted, judicial enforcement actions (civil and criminal) offer a second level of enforcement authority. They may be initiated by the State or by private citizens. Judicial actions are typically initiated to recover costs incurred for cleanup, to assess civil penalties, to confiscate or condemn property for purposes of remedying solid waste problems, to compel compliance, or to abate nuisances. Criminal actions usually require that the violator willingly and knowingly committed the offense, whether it be a misdemeanor or felony.

An analysis of State solid waste enforcement powers and authorities was conducted in order to identify national patterns in the existing State enforcement authority framework.[3] Table 5-7 presents the results of the State enforcement study, which reviewed only State solid waste management regulations. Enforcement authorities that may be found in general public health statutes or media protection statutes were not addressed, for the most part, in the analysis.

The State enforcement study demonstrates that all States have permitting authority, although the scope of such authority varies from State to State. Most notably, permits are not required for all types of Subtitle D facilities. In addition, less than one-fourth of the States have the administrative authority to undertake direct State cleanup of Subtitle D waste sites, and only two-thirds of the States have authority to issue civil penalties. The maximum penalties, evident by reviewing State laws, range from $300 per day to $100,000 per day. To the extent that enforcement authority is

Table 5-7. NUMBER AND PERCENTAGE OF STATES WITH ENFORCEMENT AUTHORITIES

Authority Type	Number of States[a]	Percent of States
Administrative		
Permits	51	100
Inspections	51	100
Compliance Orders	50	98
Penalties/Fines	22	43
State Cleanup	14	27
Open Dump Prohibition	25	49
Judicial: Civil		
Injunctions	41	80
Assessment of:		
Cleanup Costs	27	53
Penalties	36	71
Citizen Suits	11	22
Condemnation	3	6
Judicial: Criminal		
Misdemeanor Fines	31	61
Misdemeanor Imprisonment		
Felony Fines	13	25
Felony Imprisonment	6	12
	7	14

SOURCE: Reference 3.

[a] Includes 50 States and the District of Columbia. State solid waste regulations were the primary source of information.

delegated to local governments, penalties may be less. Also, criminal sanctions are not a universal feature of State solid waste enforcement frameworks.

Inspection Program

The Subtitle D census contains data on the number and frequency of State inspections at Subtitle D facilities in 1984 (excluding waste piles). Table 5-8 presents these data in the aggregate; a breakdown of inspection data by facility type is presented in Section 5.3. The data indicate that landfills and SIs have been the primary focus of State inspection efforts, and that landfills are inspected more often than any other type of facility.

The census also reports whether or not States and territories used checklists for their inspections. The summary results indicate that 71.5 percent used checklists for landfill inspections, and that 30.4 percent did so for LAUs. No summary results were available for SIs.

Table 5-8. NUMBER OF INSPECTIONS AT SUBTITLE D FACILITIES IN 1984[a]

Facility Type[a]	Number of Inspections	Percentage of Units Inspected Yearly or More Often
Landfills	32,852	77
Surface impoundments	48,103	56
Land application units	8,085	19

SOURCE: Reference 1.

[a] Data were not available on waste piles.

Table 5-9. NUMBER OF FACILITIES WITH AT LEAST ONE VIOLATION IN 1984

Type of Facility[a]	Ground-water Contamination	Surface Water Contamination	Air Contamination	Methane Control	Operational Deficiencies
Landfills	720	758	950	189	5,973
Surface Impoundments	677	909	213	NA	4,907
Land application units	66	126	22	NA	293

SOURCE: Reference 1.

[a] Data were not available on waste piles.

Discovery of Violations

The Subtitle D census contains data on the number and type of violations found by States and territories at Subtitle D facilities in 1984 (except for waste piles). Table 5-9 presents these data in aggregate form. A breakdown of the data by facility type is presented in Section 5.3. The data indicate that the most commonly cited violations at Subtitle D facilities in 1984 involved facility operating requirements. A significant number of ground-water, surface water, and air contamination violations was also cited.

Enforcement Actions

The Subtitle D census does not contain any data on enforcement actions from State Subtitle D programs. However, the National Solid Waste Survey[6] includes limited enforcement data on the number of actions brought against Subtitle D facility owners/operators in 1983. In that year, 897 State actions were brought against municipalities and counties, and 1,158 against private firms and individuals. An additional 931 unclassified actions were filed in 1983.

5.3 FACILITY-SPECIFIC STATE REGULATIONS

The regulations reviews[2] contain detailed information on the State and territorial requirements that apply to the various types of Subtitle D facilities. This regulatory information is discussed under the following headings: permitting and administrative requirements, design criteria, operation and maintenance standards, location standards and restrictions, monitoring requirements, closure and post-closure requirements, and financial responsibility requirements. The discussion that follows presents a summary of State and territorial regulations for each facility type. More detailed information on what requirements are imposed by which States appears in tabular form in Appendix D.

An additional review was conducted in 1987 of State and territorial regulatory programs[8] that focused primarily on landfill design criteria (i.e., liners and leachate collection systems), ground-water monitoring, final cover, and corrective action. This review updated selected provisions of the regulations reviews[2], as discussed above, that were conducted in 1986. The data collected for the 1987 updated regulation review are summarized in the following landfill discussion. More detailed information is presented in tabular form in Appendix D.

5.3.1 LANDFILLS

Permitting and Administrative Requirements

According to the Subtitle D census, most States and territories require some permit/plan approval or license/registration for the various types of landfills (all but one have such requirements for municipal solid waste landfills). Out of a total of 16,416 landfills, 8,422 (51 percent) have permits and 2,686 (16 percent) have licenses. Table 5-10 presents these data by landfill type.

Table 5-10. NUMBER OF SUBTITLE D LANDFILLS WITH PERMITS AND LICENSES

Landfill Type	Number of Landfills with Permits or Approved Plans	Number of Landfills with Licenses or Registrations
Municipal waste	5,444	2,206
Industrial waste	1,392	319
Demolition debris only	1,377	150
Other	209	11
Total	8,422	2,686

SOURCE: Reference 1.

Most available data on specific permit information requirements, contained in the regulations reviews, are limited to municipal solid waste landfills (MSWLFs). These data are presented in Table D-1 of Appendix D and indicate that the States and territories vary widely in permit information requirements for MSWLFs. Most require some information on soil conditions, the location of surface water, and a determination of surface water background quality. Fewer have requirements with respect to total acreage, life of the facility, and future use of the property. About half require certification of the permit application by a registered professional engineer.

Design Criteria and Standards

The regulations reviews[2] indicate that 50 States and territories have a general performance standard that requires the owner/operator of an MSWLF to control the generation, storage, collection, transportation, processing and reuse, and disposal of solid waste in a safe, sanitary, aesthetically acceptable, and environmentally sound manner. Few specific design requirements have been promulgated. The data on requirements for MSWLFs are presented in Table D-2 of Appendix D. Design requirements imposed by those States and territories typically include run-on/run-off controls and, to a lesser extent, leachate management and gas controls. Eighteen States have liner design specifications, for both natural and synthetic liners.

The 1987 updated regulation review[8] indicates that 24 States and territories have liner requirements and 27 States and territories have leachate collection system requirements. An additional 19 States and territories may specify liners and 15 States and territories may specify leachate collection systems through guidance rather than regulations. The data on requirements for MSWLFs from the 1987 updated regulation review[8] are presented in Table D-3 of Appendix D.

Operation and Maintenance Standards

Fifty-two States and territories have established minimum standards for the operation and maintenance of MSWLFs. Requirements regarding the operation and maintenance of MSWLFs are presented in Table D-4 of Appendix D. Most States and territories employ a fairly consistent set of controls, including waste management, leachate control, daily cover, safety requirements, and other controls, though only 22 States employ gas controls at their MSWLFs.

Location Standards and Restrictions

Forty-four States and territories have some sort of location standards or restrictions applicable to MSWLFs. The different requirements, ranging from flood protection and minimum distances to restrictions with respect to critical habitat, geologically sensitive areas, and soil conditions, are presented in Table D-5 of Appendix D. As shown in Table D-5, 39 States specify minimum distances to man-made or natural structures, and 36 have some form of flood control restrictions. Only 19 States and territories have location standards restrictions applicable to critical habitats, geologically sensitive areas, or soil conditions and only a few include location standards for wetlands (6 States), seismic impact zones (3 States), and subsidence-prone areas (6 States) in their solid waste regulations.[9]

Monitoring Requirements

The regulations reviews[2] indicate that 42 States and territories require ground-water monitoring, 23 require leachate monitoring, and 3 of the States or territories that require leachate monitoring do not require ground-water monitoring. Ten States require surface water monitoring systems to be installed and operated around MSWLFs and no States or territories require air monitoring. The data on types of monitoring are presented in Table D-6 of Appendix D.

From the 1987 updated regulation review[8] it was determined that 38 States and territories require ground-water monitoring through regulation and an additional nine States and territories may specify ground-water monitoring through guidance. These data are presented in Table D-3 of Appendix D.

Closure, Post-Closure, and Financial Responsibility Requirements

Forty-four States and territories have some sort of regulatory requirements for both closure and post-closure, and 20 of these require some form of financial assurance. Seven States have requirements only for closure. The differing requirements are presented in Table D-7 of Appendix D.

The 1987 updated regulation review[8] indicates that 49 States and territories require a final cover at closure and an additional 3 States and territories may specify final cover through guidance. Fourteen States and territories require corrective action for ground-water contamination and 18 States and territories may specify corrective action through guidance. These data are presented in Table D-3 of Appendix D.

Enforcement Efforts

The Subtitle D census contains limited data on State enforcement activities at Subtitle D landfills. The number and frequency of inspections and the number and type of violations discovered at landfills are included, but no data are available on enforcement actions and compliance rates.

Census data on inspections, presented in Table 5-11, demonstrate the special attention given MSWLFs compared to the other types of landfills. This is also confirmed by the data on frequency of inspections shown in Table 5-12.

Census data on violations discovered at landfills are presented in Table 5-13. These data indicate that while most of the violations reported in 1984 were for operational deficiencies, a significant number were reported for ground-water, surface water, and air contamination violations. It should be noted that the States used their own definitions of "contamination" in reporting these data, and thus both minor and serious contamination incidents are likely to be included.

Table 5-11. NUMBER OF INSPECTIONS OF SUBTITLE D LANDFILLS IN 1984

Landfill Type	Number of Inspections During 1984	Number of Landfills
Municipal waste	24,865	9,284
Industrial waste	4,354	3,511
Demolition debris only	2,834	2,591
Other	799	1,030
Total	32,852	16,416

SOURCE: Reference 1.

Table 5-12. FREQUENCY OF INSPECTION OF SUBTITLE D LANDFILLS

Inspection Rate	Municipal Waste	Industrial Waste	Demolition Debris	Other	Total
Response Rate	90%	94%	92%	98%	91%
Never inspected	431 (5.1%)	157 (4.8%)	212 (9.2%)	64 (6.4%)	864 (5.8%)
Less than once every two years	347 (4.1%)	376 (11.4%)	202 (8.8%)	10 (1.0%)	935 (6.2%)
Once every two years	776 (9.3%)	87 (2.6%)	308 (13.4%)	301 (30.0%)	1,472 (9.8%)
Once a year	2,609 (31.1%)	512 (15.3%)	580 (25.2%)	513 (51.0%)	4,214 (28.1%)
Twice a year	1,272 (15.2%)	482 (14.6%)	733 (31.9%)	100 (9.9%)	2,587 (17.3%)
Four times a year	1,548 (18.5%)	416 (12.6%)	142 (6.2%)	15 (1.5%)	2,121 (14.2%)
More than four times a year	1,279 (15.3%)	1,243 (37.7%)	93 (4.0%)	3 (0.2%)	2,618 (17.5%)
Other	122 (1.5%)	24 (0.7%)	30 (1.3%)	0	176 (1.2%)
Total[a]	8,384 (100%)	3,297 (100%)	2,300 (100%)	1,006 (100%)	14,987 (100%)

SOURCE: Reference 1.

[a] Percentages are rounded and may not total 100 percent.

Table 5-13. NUMBER OF LANDFILLS BY TYPE OF VIOLATION IN 1984

Violation Type	Municipal Waste	Industrial Waste	Demolition Debris Only	Other	Total
Ground-water contamination	586	111	16	7	720
Ground-water monitoring program deficiencies	834	117	82	108	1,141
Surface-water contamination	660	50	42	6	758
Air contamination	845	18	33	54	950
Methane control deficiencies	180	8	0	1	189
Operational deficiencies and other minor violations	4,784	433	531	225	5,973
Other violations in 1984	222	13	7	0	242

SOURCE: Reference 1.

5.3.2 SURFACE IMPOUNDMENTS

Sixteen of the States and territories studied for the regulations reviews have regulations that address SIs.

Permitting and Administrative Requirements

With a few exceptions, each of the 16 States and territories studied requires that an application, license, or permit be issued before facilities can become operational. As shown in Table 5-14, a significant number of SIs actually have permits or approved plans, while relatively few have licenses or registrations. Specific permit information requirements that apply to SIs--ranging from soil conditions, ground-water and surface water information to future use of the property--are shown in Table D-8 of Appendix D. In most cases, the requirements include certification of the permit application by a professional engineer and, to a lesser extent, surface water and ground-water information.

Table 5-14. NUMBER OF SUBTITLE D SURFACE IMPOUNDMENTS WITH PERMITS AND LICENSES

Surface Impoundment Type	Number of Surface Impoundments with Permits or Plan Approvals	Number of Surface Impoundments with Licenses or Registrations
Municipal sewage sludge	1,121	0
Municipal run-off	365	0
Industrial waste	7,747	354
Agricultural waste	10,505	210
Mining waste	11,218	77
Oil or gas waste	59,295	0
Other	5,227	0
Total	95,478	641

SOURCE: Reference 1.

Design Criteria and Standards

Of the 16 States and territories that have SI requirements, 11 have facility design criteria. As can be seen in Table D-9 of Appendix D, not all of these specific criteria are implemented in each of the 11 States. Nine specify security requirements and run-on/run-off controls, eight require leachate management, and seven include some form of natural or synthetic liner design specifications.

Operation and Maintenance Standards

Fourteen of the 16 States and territories with SI requirements have established minimum operation and maintenance standards. The reasons typically cited for promulgating such standards are to minimize nuisances, to protect public health and safety, and to prevent pollution of the environment. Despite this uniformity of purpose, the breadth and specificity of these minimum standards vary widely among the States and territories, as shown in Table D-10 of Appendix D, and the actual levels or methods of performance are frequently left to the discretion of the enforcement agency. Thirteen States have some sort of leachate controls, 11 have safety standards, and ten have other operation and maintenance controls. Only six States have standards relative to waste management, and only two have standards for cover.

Location Standards and Restrictions

Twelve States and territories have location standards for SIs. The distribution of the specific location standards and restrictions, ranging from flood protection to critical habitat control, is shown in Table D-11 of Appendix D. Eleven States have flood protection standards, nine have minimum distance requirements, five have geologically sensitive area restrictions, and four have critical habitat controls. Only two States have standards relative to soil conditions. As with landfills, States are more likely to restrict sites in floodplains and within specified distances to man-made structures and natural resources.

Monitoring Requirements

Fourteen States require ground-water, surface water, leachate, or air monitoring, as illustrated in Table D-12 of Appendix D. Ground-water monitoring is required in 11 of these States, leachate in seven, air in eight, and surface water in only four States.

Closure, Post-Closure, and Financial Responsibility Requirements

Eleven of the 16 States and territories have included closure requirements in their regulations. These are shown in Table D-13 of Appendix D. Ten States have requirements covering post-closure, and six of these States impose financial responsibility requirements as well.

Enforcement Efforts

The Subtitle D census contains limited data on State enforcement activities at Subtitle D SIs. Though the number and frequency of inspections and the number and type of violations discovered are included, no data on enforcement actions and compliance rates are provided. The inspection data presented in Table 5-15 show the number of inspections conducted during 1984 at various types of SIs. While the total number of SIs is shown in this table to place the numbers of inspections in perspective, a true indication of frequency of inspections cannot be deduced. For an indication of the frequency of inspections at SIs, the reader is referred to Table 5-16. The data show that municipal run-off SIs are inspected the most frequently, with 73 percent inspected one or more times each year.

Table 5-15. NUMBER OF INSPECTIONS OF SUBTITLE D SURFACE IMPOUNDMENTS IN 1984

Surface Impoundment Type	Number of Inspections During 1984	Number of Surface Impoundments
Municipal sewage sludge	1,079	1,938
Municipal run-off	1,768	488
Industrial waste	6,164	16,232
Agricultural waste	3,765	17,150
Mining waste	7,674	19,813
Oil or gas waste	26,340	125,074
Other	1,313	11,118
Total	48,103	191,813

SOURCE: Reference 1.

Table 5-16. FREQUENCY OF INSPECTION OF SUBTITLE D SURFACE IMPOUNDMENTS

Inspection Rate	Municipal Sewage Sludge	Municipal Run-off	Industrial Waste	Agricultural Waste	Mining Waste	Oil or Gas Waste	Other	Total
Response rate	93%	98%	73%	88%	38%	77%	47%	72%
Never inspected	37 (2.1%)	34 (7.1%)	191 (1.6%)	3,634 (24.2%)	658 (8.8%)	11,478 (11.9%)	3 (0.06%)	16,035 (11.6%)
Less than once every two years	401 (22.4%)	59 (12.3%)	2,981 (25.2%)	5,568 (37.1%)	927 (12.4%)	15,239 (15.7%)	104 (2.0%)	25,279 (18.2%)
Once every two years	208 (11.6%)	30 (6.3%)	2,835 (24.0%)	1,013 (6.7%)	3,294 (44.0%)	7,344 (7.6%)	108 (2.1%)	14,832 (10.7%)
Once a year	851 (47.9%)	106 (22.1%)	4,645 (39.3%)	2,918 (19.4%)	2,009 (26.8%)	60,152 (62.2%)	425 (8.2%)	71,106 (51.3%)
Twice a year	234 (13.0%)	24 (5.0%)	498 (4.2%)	413 (2.8%)	100 (1.3%)	1,426 (1.5%)	27 (0.5%)	2,722 (2.0%)
Four times a year	61 (3.4%)	82 (17.1%)	234 (2.0%)	3 (0.1%)	51 (0.7%)	406 (0.4%)	222 (4.3%)	1,059 (0.8%)
More than four times a year	2 (0.1%)	138 (28.8%)	164 (1.4%)	0	206 (2.7%)	740 (0.8%)	0	1,250 (0.9%)
Other	0	6 (1.3%)	275 (2.3%)	1,465 (9.8%)	249 (3.3%)	0	4,324 (82.9%)	6,319 (4.6%)
Total[a]	1,794 (100%)	479 (100%)	11,823 (100%)	15,014 (100%)	7,494 (100%)	96,785 (101%)	5,213 (100%)	138,602 (100%)

SOURCE: Reference 1.

[a] Percentages are rounded and may not total 100 percent.

Census data on violations at SIs are presented in Table 5-17. As with landfills, these data indicate that while most of the violations reported in 1984 were for operational deficiencies, a significant number were reported for ground-water, surface water, and air contamination violations. As mentioned previously, the States' definitions of "contamination" vary.

Table 5-17. NUMBER OF SURFACE IMPOUNDMENTS BY TYPE OF VIOLATION IN 1984

Violation Type	Municipal Sewage	Municipal Run-off	Industrial Waste	Agricultural Waste	Mining Waste	Oil or Gas Waste	Other	Total
Ground-water contamination	35	32	416	29	48	111	6	677
Ground-water monitoring program deficiencies	28	12	317	34	137	110	5	643
Surface-water contamination	24	18	279	189	249	128	22	909
Air contamination	20	12	145	21	5	10	0	213
Operational deficiencies[a]	137	37	616	672	534	2,893	18	4,907
Other violations in 1984	0	0	0	0	7	0	0	7

SOURCE: Reference 1.

[a] Includes other minor violations.

5.3.3 LAND APPLICATION UNITS

Twenty-three of the States and territories reviewed in the regulations reviews have regulations that address LAUs.

Permitting and Administrative Requirements

Out of a total of 18,889 LAUs, 12,502 (66 percent) have permits or approved plans, and 410 (2 percent) have licenses or registrations. These numbers are presented, by LAU type, in Table 5-18. Twenty-two of the 23 States and territories require an application, license, or permit before facilities can become operational. The range of specific permit information requirements is shown in Table D-14 of Appendix D.

Table 5-18. NUMBER OF SUBTITLE D LAND APPLICATION UNITS WITH PERMITS AND LICENSES

Land Application Unit Type	Number with Permits or Approved Plans	Number with Licenses or Registrations
Municipal sewage sludge	7,955	297
Industrial waste	3,331	113
Oil or gas waste	697	0
Other	519	0
Total	12,502	410

SOURCE: Reference 1.

In most State and territory regulations, the governing agency reserves the right to require any additional information deemed necessary. Along the same lines, nearly all States have specific administrative procedures that allow exemptions, variances, and restrictions based on a case-by-case evaluation of site-specific circumstances.

Design Criteria and Standards

Sixteen States and territories have requirements pertaining to facility design. The variability with respect to the enforcement of such requirements across States is shown in Table D-15 of Appendix D. Most States require security (14) and run-on/run-off controls (13) and, to a lesser extent, leachate management (7) and temperature storage system design specifications (7). Only three States have air protection design criteria, and only one State has requirements pertaining to environmental criteria.

Operation and Maintenance Standards

Twenty-one of the 23 States and territories with restrictions on LAUs have operation and maintenance regulations. Table D-16 of Appendix D shows which of these regulatory areas are covered by the different States and territories. Eighteen States and territories require safety controls, 16 have waste management and/or waste application controls, seven have crop management restrictions, and six have leachate management restrictions.

Location Standards and Restrictions

Seventeen States and territories have location standards and restrictions that pertain to LAUs, as shown in Table D-17 of Appendix D. Consistent with other types of Subtitle D facilities, LAU location controls usually include floodplain and minimum distance restrictions. Relatively few States have requirements relative to critical habitat, geologically sensitive areas, or soil conditions.

Monitoring Requirements

Sixteen States and territories have monitoring requirements. The distribution of these requirements across States and territories is shown in Table D-18 of Appendix D. Fifteen call for ground-water monitoring, but only eight require soil monitoring. Soil, air, and leachate monitoring are required by eight, seven, and six States and territories, respectively.

Closure, Post-Closure, and Financial Responsibility Requirements

State and territory regulatory requirements for LAU closure, post-closure, and financial responsibility vary widely. The 13 that have such regulations are shown in Table D-19 of Appendix D. No States or territories are reported to have liability requirements for LAUs.

Enforcement Efforts

The Subtitle D census contains limited data on State enforcement activities at Subtitle D LAUs. These include the number and frequency of inspections and the number and type of violations discovered. The inspection data, presented in Table 5-19, indicate that over twice as many inspections occurred at municipal sewage sludge units as at other types. On the other hand, the data on frequency of inspection shown in Table 5-20 reveal that most municipal sludge units were inspected once every two years or less, whereas most oil and gas units were inspected once a year or more. Census data on violations at LAUs are presented in Table 5-21. As with landfills and SIs, these data indicate that most of the violations reported in 1984 were for operational deficiencies, but ground-water, surface water, and air contamination violations were reported as well.

Table 5-19. NUMBER OF INSPECTIONS OF SUBTITLE D LAND APPLICATION UNITS IN 1984

Land Application Unit Type	Number of Inspections During 1984	Number of Land Application Units
Municipal sewage sludge	5,326	11,937
Industrial waste	1,601	5,605
Oil or gas waste	1,124	726
Other	34	621
Total	8,085	18,889

SOURCE: Reference 1.

Table 5-20. FREQUENCY OF INSPECTION OF SUBTITLE D LAND APPLICATION UNITS

Inspection Rate	Municipal Sewage Sludge	Industrial Waste	Oil and Gas Waste	Other	Total[a]
Response rate	95%	99%	100%	100%	97%
Never inspected	388 (3.4%)	1,308 (23.7%)	15 (2.1%)	71 (11.4%)	1,782 (9.8%)
Less than once every two years	6,489 (57.2%)	2,487 (45.0%)	6 (0.8%)	46 (7.4%)	9,028 (49.5%)
Once every two years	1,403 (12.4%)	845 (15.3%)	33 (4.5%)	28 (4.5%)	2,309 (12.7%)
Once a year	1,787 (15.8%)	639 (11.6%)	175 (24.1%)	26 (4.2%)	2,627 (14.4%)
Twice a year	254 (2.2%)	126 (2.3%)	465 (64.0%)	0	845 (4.6%)
Four times a year	98 (0.9%)	21 (0.4%)	4 (0.6%)	0	123 (0.7%)
More than four times a year	182 (1.6%)	10 (0.2%)	8 (1.1%)	0	200 (1.1%)
Other	743 (6.5%)	94 (1.7%)	20 (2.8%)	450 (72.5%)	1,307 (7.2%)
Total[a]	11,344 (100%)	5,530 (100%)	726 (100%)	621 (100%)	18,221 (100%)

SOURCE: Reference 1.

[a] Percentages are rounded and may not total 100 percent.

Table 5-21. NUMBER OF LAND APPLICATION UNITS BY TYPE OF VIOLATION IN 1984

Violation Type	Municipal Sewage Sludge	Industrial Waste	Oil or Gas Waste	Other	Total
Ground-water contamination	17	45	2	2	66
Ground-water monitoring program deficiencies	14	41	8	1	64
Surface water contamination	17	60	25	24	126
Air contamination	12	10	0	0	22
Operational deficiencies and other minor violations	115	88	82	8	293
Other violations in 1984	10	0	0	0	10

SOURCE: Reference 1.

5.3.4 WASTE PILES

Thirty States and territories have regulations that address waste piles.

Permitting and Administrative Requirements

Thirty States and territories require a permit, license, or application for waste piles. Table D-20 of Appendix D presents a matrix of some of the permit requirements. Specific permit information requirements for waste piles are limited in scope and vary considerably among the States and territories, but typically require information on soil conditions, surface water location, and ground-water elevation and flow. As with the other types of facilities, most States require certification of permit applications by a professional engineer.

Design Criteria and Standards

Twenty-two States and territories have design criteria applicable to waste piles. Specific requirements for waste piles range from liner specifications to leachate management and decomposition gas controls. The distribution of these requirements is presented in Table D-21 of Appendix D. Nineteen States have security requirements, and 13 require run-on/run-off controls.

Very few States have liner design criteria (7) or gas control standards (6), and no State or territory has leachate collection design standards.

Operation and Maintenance Standards

Twenty-seven States and territories impose some sort of operation and maintenance standards on waste piles. Specific standards range from waste composition requirements to vector, dust, and noise controls. The distribution of these requirements among the States is presented in Table D-22 of Appendix D. Most of these States have safety standards (26) and other operation and maintenance standards (25). A relatively moderate amount have waste management restrictions (10) and leachate controls (9), while relatively few have gas controls (4) or cover requirements (3).

Location Standards and Restrictions

Fifteen States and territories have some sort of location standards or restrictions applicable to waste piles. As with other facility types, the most common location requirements apply to floodplains (11) and minimum distances (9). These location standards and restrictions are presented in Table D-23 of Appendix D. The least common restrictions found were for critical habitat (3), geologically sensitive areas (2), and soil conditions (2).

Monitoring Requirements

Sixteen States and territories impose monitoring requirements on waste piles. The specific types of monitoring required (i.e., ground water, surface water, leachate, or air) vary considerably. These requirements are presented in Table D-24 of Appendix D. More States require ground-water monitoring systems (14) and leachate monitoring and control (10) than require surface water (5) or air monitoring (2).

Closure, Post-Closure, and Financial Responsibility Requirements

Fourteen States and territories have closure and post-closure maintenance requirements for waste piles. These are presented in Table D-25 of Appendix D, and include six States that impose financial responsibility requirements for waste piles.

Enforcement Efforts

The Subtitle D census does not contain data on waste piles, so there are no current, available nationwide data on the number and frequency of State inspections of waste piles or the number and types of violations.

5.4 SUMMARY

This chapter has presented data on State and territorial Subtitle D programs. The Subtitle D census indicated that most States (39) have two to as many as eight different agencies administering parts of the Subtitle D program. Solid waste and water-related agencies were most frequently noted.

The average number of dollars reported per State or territory spent on Subtitle D activities in 1984 was $785,649. Approximately 85 percent of this funding was attributed to State sources, and only 7.5 percent came from Federal sources (primarily through water agencies). The census also indicated that approximately 858 person-years were committed to Subtitle D functions by the States and territories in 1984. These budget and person-hour figures are very rough and are most likely underestimates.

The Subtitle D activities most often pursued are surveillance/enforcement and permitting/licensing. The census indicated that States perceive that Subtitle D program effectiveness could be improved by expanding surveillance and enforcement activities.

Although most States have permitting authority, the scope of such authority varies from State to State. As a result, approximately one-half of the Subtitle D facilities do not have permits. Most States have the authority to inspect (90 percent) and to issue compliance orders (73 percent). Landfills are inspected more frequently than are SIs or LAUs. Few States have in their solid waste management laws and regulations authority to clean up a site that is contaminating the environment. This authority and others may, however, exist in other related statutes.

Most States do not have solid waste regulations that are equivalent in effect to the Federal criteria (40 CFR Part 257), although some do have distinctive and innovative approaches to implementation, such as the development of a class system for waste streams and disposal facilities. Facility-specific State regulations are also presented in this chapter. More detailed information can be found in Appendix D.

5.5 REFERENCES

1. Westat, Inc. Census of State and Territorial Subtitle D Nonhazardous Waste Programs, Contract 68-01-7047, U.S. Environmental Protection Agency, Washington, D.C., 1986.

2. PEI Associates, Inc. State Subtitle D Regulations on Landfills, Surface Impoundments, Land Treatment, and Waste Piles, Draft, Vols. I-IV, Contract 68-01-7075/02-3890, U.S. Environmental Protection Agency, Washington, D.C., 1986.

3. Radian Corporation. Review of State Enforcement Powers and Authorities under RCRA Subtitle D, U.S. Environmental Protection Agency, Washington, D.C., 1987.

4. NUS Corporation. State Regulatory Equivalency Analysis of the U.S. EPA Classification Criteria for Solid Waste Management Facilities, 40 CFR Part 257, U.S. Environmental Protection Agency, Washington, D.C., 1987.

5. 752 Federal Reports, 2nd Series, "State of Washington, Department of Ecology v. U.S. Environmental Protection Agency".

6. Association of State and Territorial Solid Waste Management Officials. National Solid Waste Survey, Unpublished, 1984.

7. U.S. Environmental Protection Agency. Inventory of Open Dumps, Washington, D.C., 1985.

8. U.S. Environmental Protection Agency. Draft Background Document: Updated Review of Selected Provisions of State Solid Waste Regulations, Criteria for Municipal Solid Waste Landfills (40 CFR Part 258), Washington, D.C., 1987.

9. NUS Corporation. Letter and attachment from D. Worley, NUS Corporation to J. Dorian, U.S. Environmental Protection Agency. Review of Current Statutes and Regulations for Subtitle D Location Bans. December 30, 1986.

Appendix A.

40 CFR Part 257

CRITERIA FOR CLASSIFICATION OF SOLID WASTE DISPOSAL FACILITIES AND PRACTICES

PART 257 -- CRITERIA FOR CLASSIFICATION OF SOLID WASTE DISPOSAL FACILITIES AND PRACTICES

Sec.
257.1 Scope and purpose.
257.2 Definitions.
257.3 Criteria for classification of solid waste disposal facilities and practices.
257.3-1 Floodplains.
257.3-2 Endangered species.
257.3-3 Surface water
257.3-4 Ground water.
257.3-5 Application to land used for the production of food-chain crops. (Interim final).
257.3-6 Disease.
257.3-7 Air.
257.3-8 Safety.
257.4 Effective date.

Authority: Sec. 1008(a)(3) and Sec. 4004(a), Pub. L. 94-580, 90 Stat. 2803 and 2815 (42 U.S.C. 6907(a)(3) and 6944(a)); Sec. 405(d), Pub. L. 95-217, 91 Stat. 1606 (33 U.S.C. 1345(d)).

(Amended by 46 FR 47051, September 23, 1981).

§257.1 Scope and purpose.

(a) These criteria are for use under the Resource Conservation and Recovery Act (the Act) in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health or the environment. Unless otherwise provided, these criteria are adopted for purposes of both Section 1008(a)(3) and Section 4004(a) of the Act.

(1) Facilities failing to satisfy criteria adopted for purposes of Section 4004(a) will be considered open dumps for purposes of State solid waste management planning under the Act.

(2) Practices failing to satisfy criteria adopted for purposes of Section 1008(a)(3) constitute open dumping, which is prohibited under Section 4005 of the Act.

[257.1(a) amended by 46 FR 47051, September 23, 1981].

(b) These criteria also provide guidelines for sludge utilization and disposal under Section 405(d) of the Clean Water Act, as amended. To comply with Section 405(e) the owner or operator of any publicly owned treatment works must not violate these criteria in the disposal of sludge on the land.

(c) These criteria apply to all solid waste disposal facilities and practices with the following exceptions:

(1) The criteria do not apply to agricultural wastes, including manures and crop residues, returned to the soil as fertilizers or soil conditioners.

(2) The criteria do not apply to overburden resulting from mining operations intended for return to the mine site.

(3) The criteria do not apply to the land application of domestic sewage or treated domestic sewage. The criteria do apply to disposal of sludges generated by treatment of domestic sewage.

(4) The criteria do not apply to the location and operation of septic tanks. The criteria do, however, apply to the disposal of septic tank pumpings.

(5) The criteria do not apply to solid or dissolved materials in irrigation return flows.

(6) The criteria do not apply to industrial discharges which are point sources subject to permits under Section 402 of the Clean Water Act, as amended.

(7) The criteria do not apply to source, special nuclear or byproduct material as defined by the Atomic Energy Act, as amended (68 Stat. 923).

(8) The criteria do not apply to hazardous waste disposal facilities which are subject to regulation under Subtitle C of the Act.

(9) The criteria do not apply to disposal of solid waste by underground well injection subject to the regulations (40 CFR Part 146) for the Underground Injection Control Program (UICP) under the Safe Drinking Water Act, as amended, 42 U.S.C. 3007 et seq.

§257.2 Definitions.

The definitions set forth in Section 1004 of the Act apply to this part. Special definitions of general concern to this Part are provided below, and definitions especially pertinent to particular sections of this Part are provided in those sections.

"Disposal" means the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground waters.

"Facility" means any land and appurtenances thereto used for the disposal of solid wastes.

"Leachate" means liquid that has passed through or emerged from solid waste and contains soluble, suspended or miscible materials removed from such wastes.

"Open dump" means a facility for the disposal of solid waste which does not comply with this part.

"Practice" means the act of disposal of solid waste.

"Sanitary landfill" means a facility for the disposal of solid waste which complies with this part.

"Sludge" means any solid, semisolid, or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control facility or any other such waste having similar characteristics and effect.

"Solid waste" means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved materials in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act, as amended (86 Stat. 880), or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923).

("Solid waste" definition corrected by 44 FR 58910, October 12, 1979).

"State" means any of the several States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa and the Commonwealth of the Northern Mariana Islands.

§257.3 Criteria for classification of solid waste disposal facilities and practices.

Solid waste disposal facilities or practices which violate any of the following criteria pose a reasonable probability of adverse effects on health or the environment:

§257.3-1 Floodplains.

(a) Facilities or practices in floodplains shall not restrict the flow of the base flood, reduce the temporary water storage capacity of the floodplain, or result in washout of solid waste, so as to pose a hazard to human life, wildlife, or land or water resources.

(b) As used in this section:

(1) "Based flood" means a flood that has a 1 percent or greater chance of recurring in any year or a flood of a magnitude equalled or exceeded once in 100 years on the average over a significantly long period.

(2) "Floodplain" means the lowland and relatively flat areas adjoining inland and coastal waters, including flood-prone areas of offshore islands, which are inundated by the base flood.

(3) "Washout" means the carrying away of solid waste by waters of the base flood.

§257.3-2 Endangered species.

(a) Facilities or practices shall not cause or contribute to the taking of any endangered or threatened species of plants, fish, or wildlife.

(b) The facility or practice shall not result in the destruction or adverse modification of the critical habitat of endangered or threatened species as identified in 50 CFR Part 17.

(c) As used in this section:

(1) "Endangered or threatened species" means any species listed as such pursuant to Section 4 of the Endangered Species Act.

(2) "Destruction or adverse modification" means a direct or indirect alteration of critical habitat which appreciably diminishes the likelihood of the survival and recovery of threatened or endangered species using that habitat

(3) "Taking" means harassing, harming, pursuing, hunting, wounding, killing, trapping, capturing, or collecting or attempting to engage in such conduct.

§257.3-3 Surface Water.

[257.3-3(a) and (b) amended by 46 FR 47051, September 23, 1981].

(a) For purposes of Section 4004(a) of the Act, a facility shall not cause a discharge of pollutants into waters of the United States that is in violation of the requirements of the National Pollutant Discharge Elimination System (NPDES) under Section 402 of the Clean Water Act, as amended.

(b) For purposes of Section 4004(a) of the Act, a facility shall not cause a discharge of dredged material or fill material to waters of the United States that is in violation of the requirements under Section 404 of the Clean Water Act, as amended.

(c) A facility or practice shall not cause non-point source pollution of waters of the United States that violates applicable legal requirements implementing an areawide or Statewide water quality management plan that has been developed and approved by the Administrator under Section 208 of the Clean Water Act, as amended.

(d) Definitions of the terms, "Discharge of dredged material," "Point source," "Pollutant," "Waters of the United States," and "Wetlands" can be found in the Clean Water Act, as amended, 33 U.S.C. 1251 et seq., and implementing regulations, specifically 33 CFR Part 323 (42 FR 37122, July 19, 1977).

§257.3-4 Ground Water.

(a) A facility or practice shall not contaminate an underground drinking water source beyond the solid waste boundary or beyond an alternative boundary specified in accordance with paragraph (b) of this section.

[257.3-4(b) revised by 46 FR 47051, September 23, 1981].

(b) (1) For purposes of Section 1008(a)(3) of the Act or Section 405(d) of the CWA, a party charged with open dumping or a violation of Section 405(e) may demonstrate that compliance should be determined at an alternative boundary in lieu of the solid waste boundary. The court shall establish such an alternative boundary only if it finds that such a change would not result in contamination of ground water which may be needed or used for human consumption. This finding shall be based on analysis and consideration of all of the following factors that are relevant:

(i) The hydrogeological characteristics of the facility and surrounding land, including any natural attenuation and dilution characteristics of the aquifer;

(ii) The volume and physical and chemical characteristics of the leachate;

(iii) The quantity, quality, and direction of flow of ground water underlying the facility;

(iv) The proximity and withdrawal rates of ground-water users;

(v) The availability of alternative drinking water supplies;

(vi) The existing quality of the ground water, including other sources of contamination and their cumulative impacts on the ground water;

(vii) Public health, safety, and welfare effects.

(2) For purposes of Sections 4004(a) and 1008(a)(3), the State may establish an alternative boundary for a facility to be used in lieu of the solid waste boundary only if it finds that such a change would not result in the contamination of ground water which may be needed or used

for human consumption. Such a finding shall be based on an analysis and consideration of all of the factors identified in paragraph (b)(1) of this section that are relevant.

(c) As used in this section:

(1) "Aquifer" means a geologic formation, group of formations, or portion of a formation capable of yielding usable quantities of ground water to wells or springs.

(2) "Contaminate" means introduce a substance that would cause:

(i) The concentration of that substance in the ground water to exceed the maximum contaminant level specified in Appendix 1, or

(ii) An increase in the concentration of the substance in the ground water where the existing concentration of that substance exceeds the maximum contaminant level specified in Appendix I.

(3) "Ground water" means water below the land surface in the zone of saturation.

(4) "Underground drinking water source" means:

(i) An aquifer supplying drinking water for human consumption, or

(ii) An aquifer in which the ground water contains less than 10,000 mg/l total dissolved solids.

(5) "Solid waste boundary" means the outermost perimeter of the solid waste (projected in the horizontal plane) as it would exist at completion of the disposal activity.

§257.3-5 Application to land used for the production of food-chain crops (interim final).

(a) *Cadmium.* A facility or practice concerning application of solid waste to within one meter (three feet) of the surface of land used for the production of food-chain crops shall not exist or occur, unless in compliance with all requirements of paragraph (a)(1)(i) through (iii) of this section or all requirements of paragraph (a)(2)(i) through (v) of this section.

(1)(i) The pH of the solid waste and soil mixture is 6.5 or greater at the time of each solid waste application, except for solid waste containing cadmium at concentrations of 2 mg/kg (dry weight) or less.

(ii) The annual application of cadmium from solid waste does not exceed 0.5 kilograms per hectare (kg/ha) on land used for production of tobacco, leafy vegetables or root crops grown for human consumption. For other food-chain crops, the annual cadmium application rate does not exceed:

Time Period	Annual Cd application rate (kg/ha)
Present to June 30, 1984	2.0
July 1, 1984 to December 31, 1986	1.25
Beginning January 1, 1987	0.5

(iii) The cumulative application of cadmium from solid waste does not exceed the levels in either paragraph (a)(1)(iii)(A) of this section or paragraph (a)(1)(iii)(B) of this section.

(A)

Soil cation exchange capacity (meg/100g)	Maximum cumulative application (kg/ha)	
	Background soil pH <6.5	Background soil pH ≥ 6.5
<5	5	5
5-15	5	10
>15	5	20

(B) For soils with a background pH of less than 6.5, the cumulative cadmium application rate does not exceed the levels below: *Provided*, that the pH of the solid waste and soil mixture is adjusted to and maintained at 6.5 or greater whenever food-chain crops are grown.

Soil cation exchange capacity (meq/100g)	Maximum cumulative application (kg/ha)
<5	5
5-15	10
>15	20

(2)(i) The only food-chain crop produced is animal feed.

(ii) The pH of the solid waste and soil mixture is 6.5 or greater at the time of solid waste application or at the time the crop is planted, whichever occurs later, and this pH level is maintained whenever food-chain crops are grown.

(iii) There is a facility operating plan which demonstrates how the animal feed will be distributed to preclude ingestion by humans. The facility operating plan describes the measures to be taken to safeguard against possible health hazards from cadmium entering the food chain, which may result from alternative land uses.

(iv) Future property owners are notified by a stipulation in the land record or property deed which states that the property has received solid waste at high cadmium application rates and that food-chain crops should not be grown, due to a possible health hazard.

(b) *Polychlorinated Biphenyls (PCBs).* Solid waste containing concentrations of PCBs equal to or greater than 10 mg/kg (dry weight) is incorporated into the soil when applied to land used for producing animal feed, including pasture crops for animals raised for milk. Incorporation of the solid waste into the soil is not required if it is assured that the PCB content is less than 0.2 mg/kg (actual weight) in animal feed or less than 1.5 mg/kg (fat basis) in milk.

(c) As used in this section:

(1) "Animal feed" means any crop grown for consumption by animals, such as pasture crops, forage, and grain.

(2) "Background soil pH" means the pH of the soil prior to the addition of substances that alter the hydrogen ion concentration.

(3) "Cation exchange capacity" means the sum of exchangeable cations a soil can absorb expressed in milliequivalents per 100 grams of soil as determined by sampling the soil to the depth of cultivation or solid waste placement, whichever is greater, and analyzing by the summation method for distinctly acid soils or the sodium acetate method for neutral, calcareous or saline soils ("Methods of Soil Analysis, Agronomy Monograph No. 9." C.A. Black, ed., American Society of Agronomy, Madison, Wisconsin, pp. 891-901, 1965).

(4) "Food-chain crops" means tobacco, crops grown for human consumption, and animal feed for animals whose products are consumed by humans.

(5) "Incorporated into the soil" means the injection of solid waste beneath the surface of the soil or the mixing of solid waste with the surface soil.

(6) "Pasture crops" means crops such as legumes, grasses, grain stubble and stover which are consumed by animals while grazing.

(7) "pH" means the logarithm of the reciprocal of hydrogen ion concentration.

(8) "Root crops" means plants whose edible parts are grown below the surface of the soil.

(9) "Soil pH" is the value obtained by sampling the soil to the depth of cultivation or solid waste placement, whichever is greater, and analyzing by the electrometric method. ("Methods of Soil Analysis, Agronomy Monograph No. 9," C.A. Black, ed., American Society of Agronomy, Madison, Wisconsin, pp. 914-926, 1965).

§257.3-6 Disease.

(a) *Disease Vectors.* The facility or practice shall not exist or occur unless the on-site population of disease vectors is minimized through the periodic application of cover material or other techniques as appropriate so as to protect public health.

(b) *Sewage sludge and septic tank pumpings (Interim Final).* A facility or practice involving disposal of sewage sludge or septic tank pumpings shall not exist or occur unless in compliance with paragraphs (b)(1), (2) or (3) of this section.

(1) Sewage sludge that is applied to the land surface or is incorporated into the soil is treated by a Process to Significantly Reduce Pathogens prior to application or incorporation, unless public access to the facility is controlled for at least 12 months and unless grazing by animals whose products are consumed by humans is prevented for at least one month. (These provisions do not apply to septic tank pumpings disposed of by a trenching or burial operation.)

(2) Septic tank pumpings that are applied to the land surface or incorporated into the soil are treated by a Process to Significantly Reduce Pathogens (as listed in Appendix II, Section A), prior to application or incorporation, unless public access to the facility is controlled for at least 12 months and unless grazing by animals whose products are consumed by humans is prevented for at least one month. (These provisions do not apply to septic tank pumpings disposed of by a trenching or burial operation.)

(3) Sewage sludge or septic tank pumpings that are applied to the land surface or are incorporated into the soil are treated by a Process to Further Reduce Pathogens, prior to application or incorporation, if crops for direct human consumption are grown within 18 months subsequent to application or incorporation. Such treatment is not required if there is no contact between the solid waste and the edible portion of the crop; however, in this case the solid waste is treated by a Process to Significantly Reduce Pathogens, prior to application; public access to the facility is controlled for at least 12 months; and grazing by animals whose products are consumed by humans is prevented for at least one month. If crops for direct human consumption are not grown within 18 months of application or incorporation, the requirements of paragraph (b)(1) and (2) of this section apply. Processes to Further Reduce Pathogens are listed in Appendix II, Section B.

(c) As used in this section:

(1) "Crops for direct human consumption" means crops that are consumed by humans without processing to minimize pathogens prior to distribution to the consumer.

(2) "Disease vector" means rodents, flies, and mosquitoes capable of transmitting disease to humans.

(3) "Incorporated into the soil" means the injection of solid waste beneath the surface of the soil or the mixing of solid waste with the surface soil.

(4) "Periodic application of cover material" means the application and compaction of soil or other suitable material over disposed solid waste at the end of each operating day or at such frequencies and in such a manner as to reduce the risk of fire and to impede vectors access to the waste.

(5) "Trenching or burial operation" means the placement of sewage sludge or septic tank pumpings in a trench or other natural or man-made depression and the covering with soil or other suitable material at the end of each operating day such that the wastes do not migrate to the surface.

§257.3-7 Air.

(a) The facility or practice shall not engage in open burning of residential, commercial, institutional or industrial solid waste. This requirement does not apply to infrequent burning of agricultural wastes in the field, silvicultural wastes for forest management purposes, land-clearing debris, diseased trees, debris from emergency clean-up operations, and ordinance.

(b) For purposes of Section 4004(a) of the Act, the facility shall not violate applicable requirements developed under a State Implementation Plan (SIP) approved or promulgated by the Administrator pursuant to Section 110 of the Clean Air Act, as amended.

[257.3-7(b) amended by 46 FR 47051, September 23, 1981].

(c) As used in this section "open burning" means the combustion of solid waste without (1) control of combustion air to maintain adequate temperature for efficient combustion, (2) containment of the combustion reaction in an enclosed device to provide sufficient residence time and mixing for complete combustion, and (3) control of the emission of the combustion products.

§257.3-8 Safety.

(a) *Explosive gases.* The concentration of explosive gases generated by the facility or practice shall not exceed:

(1) Twenty-five percent (25%) of the lower explosive limit for the gases in facility structures (excluding gas control or recovery system components); and

(2) The lower explosive limit for the gases at the property boundary.

(b) *Fires.* A facility or practice shall not pose a hazard to the safety of persons or property from fires. This may be accomplished through compliance with 257.3-7 and through the periodic application of cover material or other techniques as appropriate.

(c) *Bird hazards to aircraft.* A facility or practice disposing of putrescible wastes that may attract birds and which occurs within 10,000 feet (3,048 meters) of any airport runway used by turbojet aircraft or within 5,000 feet (1,524 meters) of any airport runway used by only piston-type aircraft shall not pose a bird hazard to aircraft.

(d) *Access.* A facility or practice shall not allow uncontrolled public access so as to expose the public to potential health and safety hazards at the disposal site.

(e) As used in this section:

(1) "Airport" means public-use airport open to the public without prior permission and without restrictions within the physical capacities of available facilities.

(2) "Bird hazard" means an increase in the likelihood of bird/aircraft collisions that may cause damage to the aircraft or injury to its occupants.

(3) "Explosive gas" means methane (CH_4).

(4) "Facility structures" means any buildings and sheds or utility or drainage lines on the facility.

(5) "Lower explosive limit" means the lowest percent by volume of a mixture of explosive gases which will propagate a flame in air at 25 °C and atmospheric pressure.

(6) "Periodic application of cover material" means the application and compaction of soil or other suitable material over disposed solid waste at the end of each operating day or at such frequencies and in such a manner as to reduce the risk of fire and to impede disease vectors' access to the waste.

(7) "Putrescible wastes" means solid waste which contains organic matter capable of being decomposed by microorganisms and of such a character and proportion as to be capable of attracting or providing food for birds.

§257.4 Effective date.

These criteria become effective October 15, 1979.

Appendix I

The maximum contaminant levels promulgated herein are for use in determining whether solid waste disposal activities comply with the ground-water criteria (§257.3-4). Analytical methods for these contaminants may be found in 40 CFR Part 141 which should be consulted in its entirety.

1. ***Maximum contaminant levels for inorganic chemicals.*** The following are maximum levels of inorganic chemicals other than fluoride:

Contaminant	Level (milligrams per liter)
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.
Selenium	0.01
Silver	0.05

The maximum contaminant levels for fluoride are:

Temperature[1] degrees Fahrenheit	Degrees Celsius	Level (Milligrams per liter)
53.7 and below	12 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

[1] Annual average of the maximum daily air temperature.

2. *Maximum contaminant levels for organic chemicals.* The following are the maximum contaminant levels for organic chemicals:

	Level (milligrams per liter)
(a) Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10, 10-Hexachloro-6,7-epoxy-1,4,4a, 5,6, 7,8a-octahydro-1,4-endo, endo-5,8-dimethano naphthalene)	0.0002
Lindane (1,2,3,4,5,6-Hexachlorocyclohexane, gamma isomer)	0.004
Methoxychlor (1,1,1-Trichloro-2,2-bis (p-methoxyphenyl) ethane)	0.1
Toxaphene ($C^{10}H^{10}C^{18}$-Technical chlorinated camphene, 67 to 69 percent chlorine)	0.005
(b) Chlorophenoxys:	
2,4-D (2,4-Dichlorophenoxy-acetic acid)	0.1
2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid)	0.01

3. *Maximum microbiological contaminant levels.* The maximum contaminant level for coliform bacteria from any one well is as follows:

(a) Using the membrane filter technique:

(1) Four coliform bacteria per 100 milliliters if one sample is taken or

(2) Four coliform bacteria per 100 milliliters in more than one sample of all the samples analyzed in one month.

(b) Using the five tube most probable number procedure (the fermentation tube method), in accordance with the analytical recommendations set forth in "Standard Methods for Examination of Water and Waste Water," American Public Health Association, 13th Ed. pp. 662-688, and using a Standard sample, each portion being one fifth of the sample:

(1) If the standard portion is 10 milliliters, coliform in any five consecutive samples from a well shall not be present in three or more of the 25 portions, or

(2) If the standard portion is 100 milliliters, coliform in any five consecutive samples from a well shall not be present in five portions in any of five samples or in more than fifteen of the 25 portions.

4. *Maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity.* The following are the maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity:

   (a) Combined radium-226 and radium 228--5 pCi/l;

   (b) Gross alpha particle activity (including radium -226 but excluding radon and uranium)--15 pCi/l.

Appendix II

A. *Processes to Significantly Reduce Pathogens.*

Aerobic digestion: The process is conducted by agitating sludge with air or oxygen to maintain aerobic conditions at residence times ranging from 60 days at 15°C to 40 days at 20°C, with a volatile solids reduction of at least 38 percent.

Air Drying: Liquid sludge is allowed to drain and/or dry on under-drained sand beds, or paved or unpaved basins in which the sludge is at a depth of nine inches. A minimum of three months is needed, two months of which temperatures average on a daily basis above 0°C.

Anaerobic digestion: The process is conducted in the absence of air at residence times ranging from 60 days at 20°C to 15 days at 35 to 55°C, with a volatile solids reduction of at least 38 percent.

Composting: Using the within-vessel, static aerated pile or windrow composting methods, the solid waste is maintained at minimum operating conditions of 40°C for five days. For four hours during this period the temperature exceeds 55°C.

Lime Stabilization: Sufficient lime is added to produce a pH of 12 after two hours of contact.

Other Methods: Other methods or operating conditions may be acceptable if pathogens and vector attraction of the waste (volatile solids) are reduced to an extent equivalent to the reduction achieved by any of the above methods.

B. *Processes to Further Reduce Pathogens*

Composting: Using the within-vessel composting method, the solid waste is maintained at operating conditions of 55°C or greater for three days. Using the static aerated pile composting method, the solid waste is maintained at operating conditions of 55°C or greater for three days. Using the windrow composting method, the solid waste attains a temperature of 55°C or greater for at least 15 days during the composting period. Also, during the high temperature period, there will be a minimum of five turnings of the windrow.

Heat drying: Dewatered sludge cake is dried by direct or indirect contact with hot gases, and moisture content is reduced to 10 percent or lower. Sludge particles reach temperatures well in excess of 80°C, or the wet bulb temperature of the gas stream in contact with the sludge at the point where it leaves the dryer is in excess of 80°C.

Heat treatment: Liquid sludge is heated to temperatures of 180°C for 30 minutes.

Thermophilic aerobic digestion: Liquid sludge is agitated with air or oxygen to maintain aerobic conditions at residence times of 10 days at 55-60°C, with a volatile-solids reduction of at least 38 percent.

Other methods: Other methods or operating conditions may be acceptable if pathogens and vector attraction of the waste (volatile solids) are reduced to an extent equivalent to the reduction achieved by any of the above methods.

Any of the processes listed below, if added to the processes described in Section A above, further reduce pathogens. Because the processes listed below, on their own, do not reduce the attraction of disease vectors, they are only add-on in nature.

Beta ray irradiation: Sludge is irradiated with beta rays from an accelerator at dosages of at least 1.0 megarad at room temperature (ca. 20°C).

Gamma ray irradiation: Sludge is irradiated with gamma rays from certain isotopes, such as ^{60}Cobalt and ^{137} Cesium, at dosages of at least 1.0 megarad at room temperature (ca. 20°C).

Pasteurization: Sludge is maintained for at least 30 minutes at a minimum temperature of 70°C.

Other methods: Other methods or operating conditions may be acceptable if pathogens are reduced to an extent equivalent to the reduction achieved by any of the above add-on methods.

Appendix B

INDUSTRIAL NONHAZARDOUS WASTE TABLES[1]

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[1] Taken from: Summary of Data on Industrial Nonhazardous Waste Disposal Practices. Science Applications International Corporation, for U.S. EPA. 1985.

Table B-1 SUMMARY OF INDUSTRIAL NONHAZARDOUS WASTE GENERATION AND MANAGEMENT

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-Site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Electrical machinery and electronic components (SIC 36)		11,500[1,2]	--[3]	391[4]	--	--	--	--	--	--	--	M	--	M[5]
	Wastewater treatment sludges	5,900[1,2]					M	M	--	--	--	--	--	--
	Plastics	5,100[1,2]					--	--	--	--	--	M	--	M
	Oils	200[1,2]					--	--	--	--	--	M	--	M
	Paint wastes	200[1,2]	--	--	--	--	--	--	--	--	--	M	--	M
Electric power generation (SIC 4911)		61,553,000[6,7]	--	1,671[4]		--	--	51	--	--	M	--	--	--
	Bottom ash (coal)	11,258,000[6,7]					--	81	--	--	M	--	--	--
	Fly ash (coal)	44,900,000[6,7]					--	43	--	--	M	--	--	--
	Flue gas desulfurization (coal) sludge	3,966,000[6,7]					--	--	--	--	M	--	--	--
	Boiler slag	--					--	81	--	--	M	--	--	--
	Fly ash (oil)	20,000[6,7]					--	--	--	--	M	--	--	--

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-Site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Fabricated[8] metal products (SIC 34)		330,000[7,9]	--	1,316[4]	--	--	--	--	--	--	20[9,10]	--	--	80[9,10]
	Wastewater treatment sludge	--					--	--	--	--	--	--	--	--
	Spent air filters (painting)	--					--	--	--	--	--	--	--	--
	Paint sludge	--					--	--	--	--	--	--	--	--
Fertilizer and other agricultural chemicals (SIC 2873-2879)		65,033,500	--	--	--	--	--	--	--	--	--	--	--	--
	Waste gypsum	43,043,600[7]					--	--	--	90	90	--	--	--
	Wet scrubber liquor	747,000[11]					--	--	--	--	--	--	--	--
	Cooling water treatment sludge	>550,800[11]					--	--	--	--	--	--	--	--
	WPPA sludge	--					--	--	--	--	--	--	--	--
	Spent catalyst	--					--	--	--	--	--	--	--	--
	Sulfur filter cakes	--					--	--	--	--	--	--	--	--
	Pesticide manufacturing wastes	20,692,100[6,12,13]					<0.1	46	0	23	--	8	69	70

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-Site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Food and kindred products (SIC 20)		7,007,600^{14,15}	--	4,960^{4}	--	--	--	--	--	--	--	--	--	--
	Paunch manure	851,100^{14,15}					2.2	2.2	15.6	--	20	80		80
	Meat sludge	382,200^{14}					--	--	M	--	--	--	--	--
	Liquid whey	411,100^{14}					0	10-15	10-15	0	20-25	75-80	0	75-80
	Unusable food	1,644,600^{14,15}					--	--	10-15	--	10-15	M	--	--
	Soil and trash	252,800^{14}					--	--	--	--	--	M	--	--
	Nonfood waste	425,200^{14}					--	--	--	--	10-15	M	--	--
	Grain mill sludge	61,600^{14,15}					--	--	--	--	--	M	--	--
	Soil (sugar prod.)	1,211,700^{14}					0	100	0	0	100	0	0	0
	Lime mud (sugar products)	1,211,700^{14}					0	100	0	0	100	0	0	0
	Excess bagasse	267,200^{14,15}					100	0	0	0	100	0	0	0
	Spent bleaching	60,900^{16}					--	--	--	--	--	--	--	--
	Fat/oil sludge	9,500^{16}					--	--	--	--	--			--
	Nonfood fat/oil waste	12,300^{16}					--	--	--	--	--			--
	Liquor stillage	82,200^{14}					--	--	--	--	--			--
	Unused seafood portions	123,400^{14}					--	--	--	--	--			--

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-Site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Industrial inorganic chemicals industry (SIC 2812-2819)		28,852,000[6,17]	--	--	--	--	--	--	--	--	--			--
	Brine muds	416,700[6,17]					M,LUN[18]	M,LUN	--	--	--			--
	Salt tailings	13,879,700[6,17]					--	M,LUN	--	--	--			--
	Red mud	8,371,900[6,17]					--	M,LUN	--	--	--			--
	Phosphate dust	163,000[6,17]					M,LUN	--	--	--	--			--
	Na ore residues	1,321,900[6,17]					--	M,LUN	--	--	--			--
	Lime particulates	2,588,700[6,17]					M,LUN	--	--	--	--			--
	Gypsum	1,470,600[6,17]					M,LUN	--	--	--	--			--
	Iron oxide wastes	48,500[6,17]					M,LUN	--	--	--	--			--
	Li ore residues	286,400[6,17]					M,LUN	--	--	--	--			--
	Bauxite ore wastes	132,200[6,17]					M,LUN	--	--	--	--			--
	Sulfuric ore waste	35,800[6,17]					M,LUN	--	--	--	--			--
	Calcium wastes	134,900[6,17]					M,LUN	--	--	--	--			--
	Insoluble ore residues	1,700[6,17]					M,LUN							

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-Site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Industrial organic chemicals (SIC 2819)		1,072,400[6,12]	--	4,377[4,19]	--	--	1.7	34.1	0.3	23.7	--	1.4	61.3	--
	Process wastewater	56,988,300[6,12]					0.15	60	0	7.7	--	<0.1	89	--
	Equipment washdown	265,300[6,12]					NR[20]	93.8	NR	0.1	--	NR	99	--
	Steam jet condensate	142,300[6,12]					NR	67	NR	6.1	--	NR	69	--
	Nonprocess wastewater	362,100[6,12]					NR	20.7	NR	77.7	--	NR	22.3	--
	Spent scrubber wastes	9,623,200[6,12]					NR	35.3	NR	40.3	--	0.4	59	--
	Sludges	751,800[6,12]					2.8	46.1	30.3	17.5	--	38.8	3.5	--
	Precipitates/ filtration residues	3,379,500[6,12]					47.3	22.2	NR	46.6	--	15.3	6.4	--
	Decantate/ filtrate	3,999,400[6,12]					<0.1	54.8	NR	1.8	--	0.1	76.6	--
	Spent adsorbent	58,900[6,12]					6.5	14.6	0.3	0.3	--	165	76.2	--
	Spent catalyst	12,000[6,12]					10.6	2.1	1.4	17.9	--	40.5	27.5	--
	Spent solvent	144,200[6,12]					NR	<0.1	NR	70.6	--	0.3	36.2	--
	Heavy ends	5,268,100[6,12]					1.0	8.0	0.8	25.3	--	5.4	74.1	--
	Light ends	22,522,600[6,12]					0.2	1.0	NR	41.5	--	1.1	3.4	--
	Off-spec products	520,600[6,12]					<0.1	8.2	1.9	66.2	--	2.2	23.1	--
	Containers, liners, rags	1,200[6,12]					0.9	NR	NR	47.9	--	50.9	0.2	--
	Treated solids	90,100[6,12]					33.8	NR	NR	3.9	--	61.9	0.3	--
	By-products	3,071,500[6,12]					NR	<0.1	NR	82	--	0.6	23.8	--
	Other	40,600[6,12]					NR	NR	NR	74.3	--	3.4	11.2	--

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-Site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Leather and leather products (SIC 31)		27,100[2,9]	--	104[4]	--	--	5	5	--	--	10	50	40	90
	Trimmings and shavings	8,400[2,9]					--	--	--	--	--	--	--	--
	Unfinished leather trim	1,500[2,9]					--	--	--	--	--	--	--	--
	Buffing dust	400[2,9]					--	--	--	--	--	--	--	--
	Finished leather trim	3,100[2,9]					--	--	--	--	--	--	--	--
	Finishing residues	800[2,9]					--	--	--	--	--	--	--	--
	Wastewater screenings	1,400[2,9]					--	--	--	--	--	--	--	--
	Wastewater sludge	4,600[2,9]					--	--	--	--	--	--	--	--
	Miscellaneous solid wastes	6,900[2,9]					--	--	--	--	--	--	--	--
Lumber and wood products and furniture and fixtures (SIC 24 and 25)[21]		>135,400	--	816[4]	--	--	--	--	--	--	--	--	--	--
	Bark and wood wastes	--					--	--	--	--	--	--	--	--
	Wood ash						80	--	--	--	--	--	--	--
	Wood-preserving sludges	95,500[6,9,11]					80	--	--	--	--	--	20	--
	Wastewater sludges	--					--	--	--	--	--	--	--	--
	Paint waste	34,600[6,9,11]					20	--	--	--	--		--	--
	Solvent waste	5,100[6,9,11]					20	--	--	--	--	80	--	--

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-Site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Machinery except electrical (SIC 35)		213,200[22]	--	294[4]	--	--	--	--	--	--	10[22]	70	20	90[22]
	Plastics and ceramics	--					--	--	--	--	--	--	--	--
	Fluxes	--					--	--	--	--	--	--	--	--
	Oils	--					--	--	--	--	--	--	--	--
	Wastewater treatment sludge	--					--	--	--	--	--	--	--	--
	Paint sludge	--					--	--	--	--	--	--	--	--
Pulp and paper industry (SIC 26)		9,503,200[23]	650-900	1,154[11]	0	0	72, LUN	7, LUN	--	10	--	--	--	--
	Wood wastes	2,203,100[23]					M	--	--	--	--	--	--	--
	Chemical recovery wastes	672,000[23]					M, LUN	--	--	--	--	--	--	--
	Pulp rejects	506,700[6,23]					M, LUN	--	--	--	--	--	--	--
	Wastewater sludges	2,442,200[23]					78	--	--	22	78	--	--	22
	Coal and bark ash	1,255,800[23]					M, LUN	--	--	--	--	--	--	--
	Waste paper rejects	2,423,400[23]					--	--	--	--	--	--	--	--
Petroleum refining industry (SIC 29)		1,406,000[13]	--	1,884[4]	100[13]	--	0	0	59	0	59	41[24]	0	41
	Biological sludge	866,200[13]					0	0	46	0	46	54	0	54
	FCC catalyst	162,400[13]					0	0	24	0	24	76	0	76

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-Site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Petroleum refining industry (continued)	Nonleaded tank bottoms	145,000[13]					0	0	52	0	52	48	0	48
	Primary O/S/W separator sludge	85,500[13]					0	0	37	0	37	63	0	63
	Stretford solution	47,100[13]					0	0	0	0	0	100	0	100
	HF alkylation sludge	37,900[13]					13	0	37	0	26	37	0	74
	Spent catalysts	21,000[13]					0	0	15	0	15	85	0	85
	Cooling tower sludge	17,400[13]					0	0	60	0	60	40	0	40
	Treating clays	14,900[13]					0	0	21	0	21	79	0	79
	Secondary O/S/W separator sludge	8,700[13]					0	0	44	0	44	56	0	56
Pharmaceutical industry (SIC 2831-2834)		283,000[25]	--	--	--	--	--	0	0	--	--	90	--	--
	Biological sludge	91,000[25]					--	0	0	--	--	85-90	--	--
	Filter aid, carbon sawdust, mycelium	86,400[25]					--	0	0	--	--	85-90	--	--
	Wet plant material	2,200[25]					--	0	0	--	--	M	--	--
	Fused plant steroid ingots	900[25]					--	0	0	--	--	M	--	--
	Extracted animal tissue	8,300[25]					--	0	0	--	--	M	--	--
	Fats and oils	400[25]					--	0	0	--	--	M	--	--
	Filter cake	200[25]					--	0	0	--	--	M	--	--
	Returned goods	11,000[25]					--	0	0	--	--	M	--	--

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-Site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Pharmaceutical preparations (continued)	Glass, paper, wood, aluminum, and rubber scrap	82,600^{6,25}					--	0	0	--	--	100	--	--
Plastics and resins manufacturing (SIC 2821)		49,600,000^{6,12,26}	63	235	11	--	0.8	68	0.1	58	69	1.3	78	79
	Decantates/filtrates	8,003,000^{6,12,26}					NR	34.8	NR	97.5	--	1.7	52.3	--
	Sludges	479,100^{6,12,26}					81.6	5.7	6.4	2	--	4.4	1.5	--
	Off-spec. products	323,600^{6,12,26}					1.7	9.1	NR	76.6		8.3	0.57	--
	Spent solvents	315,700^{6,12,26}					NR	<0.1	NR	99.5	--	<0.1	4.2	--
	Light ends	215,600^{6,12,26}					NR	<0.1	NR	74.4	--	NR	32.8	--
	Miscellaneous solids	134,000^{6,12,26}					2.3	NR	NR	79.0	--	84.7	2.4	--
	Precipitation/ filtration residues	34,100^{6,12,26}					21.5	28.4	NR	33.3	--	39.8	27.6	--
	Heavy ends	18,000^{6,12,26}					NR	3.4	NR	89.9	--	4.3	17.6	--
	Process Wastewater	34,078,200^{6,12,26}					NR	80.9	<0.1	41.5	--	0.4	83.6	--
	Equipment washdown	285,200^{6,12,26}					NR	92.2	NR	7.6	--	NR	100	--
	Steam jet condensate	129,500^{6,12,26}					NR	NR	NR	100	--	NR	100	--
	Spent scrubber water	2,593,600^{6,12,26}					NR	0.2	NR	65.8	--	7.7	100	--
	Nonprocess wastewater	2,951,600^{6,12,26}					NR	89	NR	89.1	--	NR	90.2	--

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-Site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Primary iron and steel manufacturing and ferrous foundries (SIC 3312-3321)		66,841,800[6,7]	--	1,380[4,27]	--	--	24,LUN	24,LUN	--	65,R[28]	--	--	--	--
	Coke breeze	1,929,900[6,7,9]					0	0	0	100,R	100	0	0	0
	Blast furnace slag	25,481,400[6,7]					0	0	0	0	0	100	100,R	100
	Blast furnace dust	1,616,000[6,7]					--	--	--	100,R	100	--	--	--
	Blast furnace sludge	1,692,000[6,7]					12,LUN	12,LUN	--	88,R	--	--	--	--
	EAF slag	4,146,300[6,7]					90	0	0	10,R,50S[29]	100	--	--	--
	EAF dust and sludge	449,400[6,7,9]					100	0	0	0	--	0	0	0
	Open hearth slag	2,231,800[6,7]					25,LUN	25,LUN	--	75,R	--	--	--	--
	Continuous casting scale	351,400[6,7]					--	--	--	100,S	--	--	--	--
	Continuous casting sludge	4,400[6,7]					--	--	--	--	--	--	--	--
	Soaking pit scale	922,000[6,7]					--	--	--	--	--	--	--	--
	Primary mill scale	2,759,400[6,7]					--	--	--	100,S	--	--	--	--
	Primary mill sludge	114,600[6,7]					--	--	--	--	--	--	--	--
	Rolling scale (hot and cold)	1,071,800[6,7]					--	--	--	100,S	100	--	--	--
	Rolling sludge (hot and cold)	5,500[6,7]					--	--	--	--	--	--	--	--

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-Site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Primary Iron and Steel Manufacturing and Ferrous Foundries (continued)	Pickle liquor sludge	--					--	--	--	--	--	--	--	--
	Galvanizing sludge	44,100[6,7]					--	--	--	100,R	100	--	--	--
	Tin plating sludge	17,600[6,7]					--	--	--	--	--	--	--	--
	Bricks and rubble	8,122,900[6,7]					100,LUN	--	--	--	--	--	--	--
	Fly ash and bottom ash	--					--	--	--	--	--	--	--	--
	Foundry sand and other wastes	15,881,300[6,7]					100	--	--	--	100	--	--	--
Primary non-ferrous metals manufacturing and nonferrous foundries (SIC 3330-3399)[30]		7,242,800	--	1,380[4,31]	--	--	--	--	--	--	--	--	--	--
	Primary aluminum wastes	343,600[6,16]					75	--	--	--	75	25	--	25
	Primary copper wastes	3,641,000[6,16]					--	--	--	--	--	--	--	--
	Primary zinc wastes	566,000[26]					--	--	--	--	--	--	--	--
	Primary lead wastes	374,500[6,26]					--	--	--	--	--	--	--	--
	Foundry sand and other wastes	2,317,700[7]					88-98	2-12	--	--	100		--	--

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Rubber and miscellaneous plastic products (SIC 30)		597,700[2,6]	--	252[4]	--	--	--	--	--	--	--	--	--	--
	Tire/inner tube waste streams	246,100[2,6,9,30]					--	--	--	--	--	--	--	--
	Rubber and plastics footwear waste streams	35,200[2,6,9,30]					--	--	--	--	--	--	--	--
	Reclaimed rubber waste streams	42,800[2,6,9,30]					--	--	--	--	--	--	--	--
	Rubber and plastics hose and belting waste-streams	58,600[2,6,9,30]					--	--	--	--	--	--	--	--
	Fabricated rubber products NEC waste streams	214,900[2,6,9,30]					--	--	--	--	--	--	--	--
	Miscellaneous plastic products waste streams	--					--	--	--	--	--	--	--	--
Soaps; other detergents; polishing, cleaning and sanitation goods (SIC 2841-2842)		34,500[6,13]	--	--	--	--	--	--	--	--	--	--	--	--
	Lost product	--					--	--	--	--	--	--	--	--
	Tower cleanouts	--					--	--	--	--	--	--	--	--
	Sludges	--					--	--	--	--	--	--	--	--
	Dust and fines	--					--	--	--	--	--	--	--	--

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (Dry Tons/Yr)	Number of On-site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Stone, clay, glass, and concrete products (SIC 32)		>20,489,100[32]	--	1,243[4]	--	--	--	--	--	--	--			--
	Silica particulates	--					--	--	--	--	--			--
	Spent diatomaceous earth	--					--	--	--	--	--			--
	Soda ash	--					--	--	--	--	--			--
	Lime	--					--	--	--	--	--			--
	Brine residues	--					--	M	--	--	--			--
	Air pollution control sludge (cement)	13,329,400					--	--	--	--	--			--
	Air pollution control sludge (clay)	4,813,800					--	--	--	M	--			--
	Lubricants	--					--	--	--	--	--			--
	Pottery sludge	SIG[33]					M	--	--	--	--			--
	Air pollution control sludge (concrete, gypsum, and plaster)	2,369,500					--	--	--	--	--			--
	Waste cullet	--					--	--	--	--	--			--
	Fiber resin masses	--					--	--	--	--	--			--

Table B-1 (continued)

Industry	Waste Type[a]	Amount of Waste Generated (dry tons/yr)	Number of On-site Nonhazardous Disposal Facilities[b]				Percent of Nonhazardous Wastes Managed[c]							
							On Site					Off Site		
			LF	SI	LT	Other	LF	SI	LT	Other	Total	Disposal	Other	Total
Textile manufacturing (SIC 22)		>49,600	--	536[4]			10	--	--	--	--	55	--	--
	Wool scouring wastes	--					--	--	--	--	--	M	--	--
	Clippings	--					--	--	--	--	--	M	--	--
	Dye containers	--					--	--	--	--	--	M	--	--
	Dry flick	--					--	--	--	--	--	M	--	--
	Waste fiber	--					--		--	--	--	M	--	--
	Wastewater treatment sludge	--					--	--	--	--	--	--	M	--
Transportation Equipment (SIC 37)		572,800[11]	--	--	--	--	--	--	--		--	--		--
	Solvents	163,000					37	--	--	--	--	--	63	--
	Paint wastes	273,200					20	--	--	--	--	--	80	--
	Metal treating wastes	136,600					100	--	--	--	--	--	--	--
Water treatment (SIC 4941)		5,463,800[34]	--	--	--	--	--	--	--	--	--	--	--	--
	Coagulation sludges	--					--	--	--	--	--	--	--	--
	Softening sludges	--					--	--	--	--	--	--	--	--

than one product or process within an industry often are combined under one listing in this table. Such combining often prevented the listing of waste management information for a given waste. This information is available in Section 4 of the Summary of Data on Industrial Nonhazardous Waste Disposal Practices.

b. LF = landfill; SI = surface impoundment; LT = land treatment.

c. Numbers in all columns represent the percentage of total wastes; note the sum of numbers in one row may exceed 100 percent if one management method is used prior to another method for the same waste stream. Also note: The management data represent the same year as the quantity data, unless otherwise indicated.

1. Data on waste types and amounts were available only for SIC 367 (represents only 2 percent of total value of 1976 product shipments for the industry).
2. 1975 data.
3. "--" = data not available.
4. Data from the Surface Impoundment Assessment National Report were collected in 1978-1980. EPA 570/9-84-002. Office of Drinking Water, December 1981.
5. M = most of the referenced wastes are managed by this technology; however, no percentage values are available in the literature.
6. Dry or wet weight not specified; assume wet weight.
7. 1983 data.
8. Data on nonhazardous waste streams in this industry are almost completely nonexistent. The list of waste types is incomplete.
9. Includes hazardous and nonhazardous wastes, depending on the source.
10. Electroplating and metal finishing only; other SIC 34 groups unknown; 1979 data.
11. 1980 data.
12. Estimated from the Industry Studies Data Base, compiled for the USEPA by SAIC.
13. 1981 data.
14. 1976 data.
15. Wet weight.
16. 1984 data.
17. 1979 data.
18. LUN = location of the management site (i.e., on site or off site) is unknown.
19. Includes the entire chemical manufacturing industry (SIC 28).
20. NR = not reported by any industries surveyed to compile the Industry Studies Data Base. See footnote number 12 above.
21. The total amount of wastes within this industry is large; however, most of the wastes are recycled; no quantities on total waste generation are available.
22. Includes only wastes from SIC 355 and 357 (representing 12 percent of total sales in SIC 15); 1977 data.
23. 1977 data.
24. Landfilling is the leading off-site disposal method for petroleum wastes.
25. 1973 data.
26. 1982 data.
27. Includes the primary nonferrous metals industry.
28. R = this waste is stockpiled prior to recycling.
29. S = stockpiled.
30. The waste streams in this category were too numerous to include in the table. See Section 4.17 of the Summary of Data on Industrial Nonhazardous Waste Disposal Practices.
31. Includes the primary iron and steel industry.
32. This estimate is known to exclude significant quantities of nonhazardous wastes.
33. SIG = significant quantities are believed to be generated.
34. Disposal methods are the subject of an ongoing survey.

Table B-2 QUALITATIVE ANALYSIS OF INDUSTRIAL NONHAZARDOUS WASTE DATA

Industry	Data Availability[a]	Relative Levels of Heavy Metals or Organics in Wastes	Prevalent Waste Management Methods
Electrical machinery and electronic components (SIC 36)	POOR: The descriptions of waste types are incomplete and waste quantity data are available only for SIC 367, which represents only 2 percent of total SIC 36 sales. (Year - 1977)	HIGH: Wastewater treatment sludges, oils, and paint wastes have potential to release heavy metals and organics. No specific analytical data are available. Since this industry generates considerable quantities of hazardous waste, some small-quantity generators may dispose hazardous wastes in on-site, land-based facilities.	General trend indicates off-site landfill disposal, based on 1977 data. Large quantities of nonhazardous wastewaters may be managed in on-site surface impoundments.
Electric power generation (SIC 4911)	GOOD: Detailed descriptions of waste types and quantities are available. Waste management data are fairly good. (Year - 1983)	MODERATE: This waste has a potential to reduce pH levels and release metals. Organics, such as naphthalenes and benzofluorenes, also may be released. Toxicity depends on the source of coal or oil being burned.	General trend is on-site disposal in clay-lined surface impoundments and landfills. Some of these facilities are synthetic-lined and have ground-water monitoring.
Fabricated metal products (SIC 34)	POOR: Waste type and quantity data are almost completely nonexistent. Some management data are available. (Years - 1976, 1979, and 1983)	HIGH: Wastewater treatment sludges, oils, and paint wastes have potential to release heavy metals and organics. No specific analytical data are available. Since this industry generates considerable quantities of hazardous wastes, some small-quantity generators may dispose of hazardous wastes in on-site, land-based facilities.	Data from 1976 indicate that 20-30 percent of wastes are managed on site in landfills and lagoons.

Table B-2 (continued)

Industry	Data Availability[a]	Relative Levels of Heavy Metals or Organics in Wastes	Prevalent Waste Management Methods
Fertilizer and Other Agricultural Chemicals (SIC 2873-2879)	MODERATE: Waste quantity and management data are very good for pesticide formulation and manufacturing, but are poor for some segments of fertilizer manufacturing. Waste types are fairly well-defined for fertilizer and detailed analyses are available for pesticides. (Years - 1980 and 1983)	HIGH: Waste gypsum piles may cause local pH and metals contamination problems. Pesticide wastes may release organics and heavy metals.	Waste gypsum is stored in unlined piles. Large quantities of wastewaters are stored or treated in surface impoundments.
Food and Kindred Products (SIC 20)	GOOD: Waste types and quantities are well defined and waste management methods are fairly well described. (Year - 1980)	LOW: Most food industry wastes are biodegradable, but may cause taste and odor problems.	Off-site landfills and land application are used extensively, with some on-site land disposal.
Industrial inorganic chemicals industry (SIC 2812 - 2819)	MODERATE: Data on waste quantities and amounts are good, but there are very little analytical data. (Year - 1979)	HIGH: Most nonhazardous wastes from this industry do not appear to contain heavy metals, but there are insufficient analytical data on these wastes. Since this industry generates considerable quantities of hazardous wastes, some small-quantity generators may dispose of hazardous wastes in on-site, land-based facilities.	On-site landfills and surface impoundments are used for most wastes. Design data on these facilities are not available.
Industrial organic chemicals (SIC 2819)	VERY GOOD: Detailed information is available on all data areas except the design features of the waste management facilities. (Years - 1981 and 1982)	HIGH: Many of the waste streams in this industry contain high levels of extremely toxic organic chemicals. Since this industry generates considerable quantities of hazardous wastes, some small-quantity generators may dispose of hazardous wastes in on-site, land-based facilities.	Most land-based disposal is performed at off-site facilities; however, approximately 34 percent of wastewater and sludges are treated in on-site impoundments prior to discharge.

Table B-2 (continued)

Industry	Data Availability[a]	Relative Levels of Heavy Metals or Organics in Wastes	Prevalent Waste Management Methods
Leather and leather tanning (SIC 31)	GOOD: Waste types and quantities are well described and general management methods are known. (Year - 1975)	MODERATE: These wastes generally contain chromium, but it is generally in the + 3-valence state.	Off-site landfills are used most commonly, and approximately 90 percent of all wastes are sent to off-site facilities. Ten percent of the wastes are managed in on-site surface impoundments and landfills.
Lumber and wood products and furniture and fixtures (SIC 24 and 25)	MODERATE: The waste types in this industry are described, but there are no dependable data on quantities of analytical results. (Year - 1980)	MODERATE: Most of the wastes (380 million MT/year) from this industry are composed of wood dust, chips, shavings, and other rejects, and most of these wastes are burned or reused. However, the ash from burning these wastes is generated in very high quantities and is high in pH.	There are no data on land disposal of wastes from this industry.
Machinery except electrical (SIC 35)	POOR: The descriptions of waste types are incomplete, and waste quantity data were available only for SIC 355 and SIC 357, which represent only 12 percent of total SIC 35 sales. (Year - 1977)	HIGH: Wastewater treatment sludges, oils, and paint wastes have potential to release heavy metals and organics. No specific analytical data are available. Since this industry generates considerable quantities of hazardous waste, some small-quantity generators may dispose of hazardous wastes in on-site, land-based facilities.	Data from 1977 indicate that 90 percent of these wastes are managed off site and that 70 percent of the total waste stream from this industry are land disposed. Ten percent of these wastes are managed on site; however, the management methods are not known.
Pulp and paper industry (SIC 26)	GOOD: The quantities and types of wastes from this industry are well described, and management methods are known for each waste type. Some data are available on waste management facility designs. (Year - 1977)	MODERATE: Organic pollutants from wood fibers may be significant. Also, coal and bark ash may contain metals. Sulfates and metals are high in some pulping wastes.	Approximately 72 percent of all wastes are managed in on-site landfill facilities. On-site surface impoundments account for 7 percent of industry wastes; about 10 percent of pulp and paper wastes are managed in on-site incinerators.

Table B-2 (continued)

Industry	Data Availability[a]	Relative Levels of Heavy Metals or Organics in Wastes	Prevalent Waste Management Methods
Petroleum refining industry (SIC 29)	VERY GOOD: All data needs were available except typical designs of waste management facilities. (Year - 1977)	HIGH: These wastes generally contain high levels of sulfides, ammonia, phenols, and oils. Some of them also contain mercaptains, benzo-a-pyrene, and other toxic organics. Since this industry generates considerable quantities of hazardous wastes, some small-quantity generators may dispose of hazardous wastes in on-site, land-based facilities.	Approximately 59 percent of the wastes are managed in on-site land application facilities. The remaining 41 percent are managed at off-site, land-based disposal sites.
Pharmaceutical preparations (SIC 2834)	GOOD: The quantities and types of wastes from this industry are fairly well-described and the general waste management methods are known. (Year - 1976)	LOW: The majority of these wastes are fermentation products and are biodegradable.	Approximately 85 to 90 percent of the wastes from this industry are managed in off-site, land-based disposal facilities.
Plastics and resins manufacturing (SIC 2821)	VERY GOOD: Detailed information is available on all data areas except the design features of the waste management facilities. (Year - 1982)	HIGH: Many of the waste streams in this industry contain organic solvents and unreacted monomers, which are frequently toxic.	Approximately 68 percent of these wastes are treated in surface impoundments, 1 percent are landfilled, and 1.5 percent are managed in off-site, land-based disposal facilities.
Primary iron and steel manufacturing and ferrous foundries (SIC 3312-3321)	GOOD: The waste types and quantities generally are available, and the compositions of each waste are known. Management methods generally are known for each waste type. (Year - 1983)	HIGH:. Many of the wastes from this industry are low in pH and may release significant quantities of heavy metals.	Approximately 25 percent of these wastes are managed in on-site impoundments and landfills. Also, 65 percent of the wastes (mainly slag) are stored in waste piles prior to recycling.
Primary nonferrous metals manufacturing and nonferrous foundries (SIC 3330-3399)	POOR: Good descriptions of the types of wastes produced by each sector, but not much analytical data. Good estimates on the quantities of each waste type, but almost no waste management data. (Year - 1984)	HIGH: Several of the waste streams contain high levels of heavy metals.	No data.

Table B-2 (continued)

Industry	Data Availability[a]	Relative Levels of Heavy Metals or Organics in Wastes	Prevalent Waste Management Methods
Rubber and miscellaneous plastic products (SIC 30)	POOR: Good data on quantities of wastes, but poor descriptions of waste characteristics and management methods. (Year - 1975)	HIGH: Data are sketchy, but indicate possibly significant levels of elastomers, carbon black, plastic resins, plasticizers, and pigments.	At least some on-site landfilling and incineration, but data are almost nonexistent.
Soaps; other detergents; polishing, cleaning, and sanitation goods (SIC 2841-2842)	POOR: Waste types poorly defined and quantity data are almost nonexistent. (Year - 1974)	LOW: Most of these wastes are composed of packaging, lost products, salts, inerts. Some organics are generated from floor polishes (plasticizers) and pine oils (solvents).	Most of these wastes are expected to be sent off site because the industry is composed of a large number of small establishments.
Stone, clay, glass, and concrete products (SIC 32)	POOR: Waste quantity data are available only for some waste types. Waste types are fairly well described, but lack analytical data. Management methods are poorly documented.	LOW: Most of the wastes produced are inert, earth-type materials. However, significant quantities of air pollution control sludges are generated, some of which may contain heavy metals.	No data; however, most wastes are expected to be managed on site due to generally low toxicity and high volumes.
Textile manufacturing (SIC 22)	POOR: Waste types are fairly well described, but there are virtually no analytical data and no data on waste quantities and management methods.	LOW: Waste descriptions indicate low organics and heavy metals, but there are virtually no analytical data to confirm this assumption.	No data.

Table B-2 (Continued)

Industry	Data Availability[a]	Relative Levels of Heavy Metals or Organics in Wastes	Prevalent Waste Management Methods
Transportation Equipment (SIC 37)	POOR: There are no data in the literature pertaining to nonhazardous waste generation and management within this industry.	HIGH: Wastes are expected to be similar in quantity and composition to those generated within SIC 34 and 35. Since this industry generates considerable quantities of hazardous wastes, some small-quantity generators may dispose of hazardous wastes in on-site, land-based facilities.	No data.
Water treatment (SIC 4941)	POOR: Waste types are fairly well described and an overall estimate on waste quantities was available; however, there were no data on waste management methods.	LOW: These wastes are composed mainly of alum and lime, but may contain some heavy metals.	No data.

[a] Data areas pursued in this study included detailed analyses on each type of waste generated by each industry, the amount of each type of waste, the types and numbers of on-site, land-based disposal methods used by each industry, the general design of these facilities, and the amounts of each waste type managed in each different type of facility. The year for which most data were found is given in parentheses.

Appendix C

MUNICIPAL WASTE LANDFILL CAPACITY PROBLEMS[1]

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[1] Presented as Appendix A in Census of State and Territorial Subtitle D Nonhazardous Waste Programs. Westat, Inc., for U.S. EPA. 1986.

NOTE: Landfill capacity status data from the municipal survey are presented in Chapter 4.

As part of the landfill section of the State Subtitle D program questionnaire, the States were asked to respond to the following:

> "Please describe any local, regional, or statewide landfill capacity problems in your State."

The responses are listed below, alphabetically by State.

Alabama. Many of the landfills are reaching capacity. It is very difficult to site new landfills due to technical requirements and public opposition.

Alaska. There is no capacity problem in Alaska as far as space, but in most areas the soil and topography are not suitable for landfills (wetlands and permafrost) due to the climate.

American Samoa. The existing landfill on the island of Tutuila is rapidly approaching capacity. With limited useable land, alternate methods of municipal waste disposal may have to be used (e.g., incineration or waste transfer to other islands).

Arizona. It is getting more difficult to site new landfills and this is causing a problem especially in the Phoenix Area, Maricopa, and Mojave Counties. Also, much of the land is federally owned and is leased on a highest bidder basis. Many of the area's lands are going back to private companies and this is causing problems siting landfills.

Arkansas. A few individual landfills are reaching capacity but no problems are foreseen in finding new locations. This is primarily due to a 1974 Arkansas ruling which said that landfills can only be turned down because of physical criteria siting problems, not because of public opposition. Additionally, zoning regulations are not restrictive in siting new landfills.

California. Most urban areas have capacity for only approximately 20 years. We need to expedite planning for future capacity.

Colorado. There are six landfills which service the greater Denver metropolitan area. Within the next three years, two with a possibility of four landfills may close. At the present time, there are no new landfills proposed to replace these facilities. If no new landfills are permitted, the Denver area may face a critical shortage of landfill space.

Connecticut. The State of Connecticut is approaching a statewide capacity shortage, estimated to become critical in late 1988. Currently 50 percent of the State's solid waste is going to nine major regional landfills. These sites will all reach their permitted capacity at about the same time because the waste flow is easily diverted to the few remaining landfills. No new municipal waste fills have been permitted in Connecticut since 1978. The permitted landfills will be used up before the planned resource recovery projects are in operation.

Delaware. No capacity problems. Increased volume at landfills in Kent and Sussex County would allow economic resource recovery facilities to be built (similar to the one presently operating in New Castle County).

Florida. An evaluation of current and projected population growth in Florida indicates a need for an estimated equivalent 2,700 acres of additional landfill area, annually, through year 1995.

Georgia. Gwinnet County, Fulton County, Douglas County, Cobb County -- these counties are located in the Atlanta area and have problems locating and zoning new sites due to public opposition. All have limited remaining landfill capacity at existing sites.

Guam. The single municipal landfill owned and operated by the Government of Guam will reach capacity in one to two years.

Hawaii. Statewide: the shortage of suitable and available sites (no community opposition) for landfills is the major concern of all the counties. Except for the City and County of Honolulu, the amount of refuse generated per day on each of the counties is too small to consider refuse-to-energy (refuse derived fuel) as an alternate method of refuse disposal. City and County of Honolulu: the three municipal landfills are rapidly approaching their capacities; the two smallest landfills will be closed within 18 months and the largest within three years. The city is finalizing a contract with a private firm to design, construct, and operate a refuse-to-energy plant.

Idaho. Approximately 12 landfills are in need of replacement due to capacity problems, eight of which are the major or only landfill for the counties in which they are located.

Indiana. Please see attached map. (Map shows estimated lifetimes of all landfills in Indiana.)

Iowa. No significant landfill capacity problems at this time statewide. Local capacity problems usually result in landfill expansion at nearby sites.

Louisiana. Lack of permitted disposal facilities for oil field waste encourages illegal dumping.

Kansas. None.

Kentucky. No response.

Maine. Some small communities, particularly those in the more remote areas not serviced by regional or commercial landfills or resource recovery projects, are in need of regional solutions. Many small municipal sites have little remaining capacity.

Maryland. Calculating the total disposal capacity for the State would be misleading. Each of the 23 Maryland Counties and Baltimore City are responsible for providing landfill capacity for their residents. This capacity at present ranges from less than one to more than 25 years. There is no programmatic mechanism for moving waste from an area with a capacity shortage to an area with a capacity surplus. The Draft State Solid Waste Plan found, in early 1985, that eight of the 24 jurisdictions had less than five years disposal capacity under permit.

Massachusetts. The capacity of Massachusetts' active landfills is actively running out. [Plus an additional page of text.]

Michigan. The capacities for solid waste disposal areas are addressed as part of the solid waste management plans which are required to be developed pursuant to Act 641.PA1978. The plan requires each county to identify disposal sites which will accept solid waste generated within its political boundaries for a five-year period. The plans are to be updated every five years with new sites identified as necessary.

Minnesota. Many landfills have five years or less for capacity and some disposal option will be needed. However, we are stressing reuse of the waste and will need less capacity. Other landfills have as much as 20 to 40 years left.

Mississippi. Within five years only about 5 percent of our landfills in Mississippi will need new sites. We expect more recycling and incineration. In general, there are no landfill capacity problems.

Missouri. No response.

Montana. Statewide many of the existing landfills are nearing capacity. In general it is very difficult to obtain new sites for landfills.

Nebraska. One municipality (pop. 18,000) has been unable to site a landfill and is transferring refuse 50 miles to another site. One major landfill has less than two years remaining life with no known effort to find a replacement at this time. Another major landfill with about the same remaining life serves 180,000 people. The city involved is seeking a new site.

Nevada. None at this time.

New Hampshire. Many landfills are reaching capacity. Also a large number have shown leachate breakouts and are under closing orders. As a result, many towns are opting for refuse-to-energy facilities.

New Jersey. Capacity problems are very severe across the state. Siting due to public opposition is the largest contributing factor to the capacity problem.

New Mexico. There are currently 61 landfills on Federal land and 12 on State land. Both entities have told the landfills that as leases expire to find new land or purchase the existing land at current market rates. Communities either do not have the funds for purchase or no other land is available or suitable. Also the "not in my backyard" syndrome is beginning to come forth in New Mexico.

New York. No response.

North Carolina. The biggest issue facing landfill operators is economic considerations needed to construct and maintain landfill facilities. With stringent rules in place for protection of the environment, new techniques and technologies are mandated for protecting the environment.

North Dakota. There are no capacity problems at this time in North Dakota.

Northern Marianas. The only solid waste facility at the present time is an open dump and although there are no capacity problems, we are looking for a new site for a landfill. We hope to find a suitable site in the not too distant future.

Ohio. There are 41 counties (out of 88) that will reach landfill capacity within four years. These are major municipal landfills that accept general solid waste (in the 41 counties).

Oklahoma. Almost every area of the State experiences some landfill capacity problems. The primary problem facing the State, however, is the lack of new landfills. Rising costs of operation, more stringent permitting requirements, and increasing public opposition have caused many landfills to close at capacity and have prevented the opening of new sites.

Oregon. Unable to estimate. Most areas of the State have at least five years of remaining life. The Portland Metropolitan Area with over one-half of the state population has less than four years of life with no new site identified. The Portland Metropolitan Area landfill that serves four counties is scheduled for closure in 1989. We are looking for a new site but have not found one yet. By July 1987, we hope to find a site. The rest of the State has no real capacity problems.

Pennsylvania. Problems in landfills are especially acute in southeast Pennsylvania. This is primarily due to closure of "full" and substandard landfills and public resistance. The Delaware and Lehigh Valleys have only a two to three year capacity and include 40 percent of the state population. Overall, the State has an estimated landfill capacity of about six years.

Puerto Rico. The landfill capacity problem is enormous in all of Puerto Rico. Almost all of the landfills operating in the Commonwealth are at the last portion of their useful life. Since Puerto Rico is a small island characterized mainly by high population densities and surface water bodies throughout the Commonwealth, it is very difficult to obtain additional land for landfill expansion or relocation. Therefore, this critical problem will only be solved by looking toward other solid waste alternatives (such as incineration).

Rhode Island. Many landfills are nearing capacity. Three landfills active in 1984 have closed.

South Carolina. Eight to 10 sites need additional acreage within the next year and two of these sites are at capacity right now.

South Dakota. There are no existing capacity problems in South Dakota.

Tennessee. The urban areas, due to population densities and lack of property of adequate acreage and approvable geology, are difficult to acquire. The public pressure to reject siting is also a factor. This situation is acute in the middle Tennessee area as geologically approvable sites are so difficult to locate.

Texas. Replacement landfills in most urban areas are coming under increasing public opposition. This has significantly increased the time required to process a permit, which diverts resources from other applications and causes an ever increasing backlog in permit evaluation.

Utah. Capacity is not a big problem but there are some localized problems with siting, especially in the industrial landfills which are in heavily populated areas and don't want to haul waste long distances.

Vermont. The Vermont Agency of Environmental Conservation recognizes two regional solid waste (i.e., landfill) capacity problems. Both regions lack landfill volume to dispose of solid waste generated within the region. Solid waste must be transported excessive distances to approved landfills. New landfills are not being developed due to lack of acceptable land, lack of resources to develop landfills, and/or regulations. One region has committed to an alternative disposal method, which has not been implemented due to regulatory and environmental issues. A statewide capacity problem has also been identified. "Approved" solid waste disposal capacity for the year 1990 is estimated to be 573,000 cubic yards to dispose of a projected 983,000 cubic yards of solid waste.

Virginia. Public resistance to siting of new facilities has caused delays in providing new facilities. Therefore, many landfills are near full and some are in heavily populated areas. Some municipal governments have moved to resource recovery facilities or contracted disposal as an alternative.

Virgin Islands. No response.

Washington. There are no capacity problems now but rather siting problems for the future for new locations especially in the metropolitan areas of Spokane and Seattle. Lack of sites and appropriate land to build landfills is primarily due to public resistance and lack of necessary geographic locations. Planning is being done for other methods of disposal such as resource recovery and burning.

West Virginia. 1) Approximately 50 percent of municipal solid waste generated in West Virginia is disposed at unpermitted facilities; 2) approximately 50 percent of permitted sites are within three to five years of exhaustion of space/capacity; 3) the northeast area of West Virginia has had severe flood damage to solid waste disposal facilities; 4) older permitted sites were designed without adequate consideration of capacity; 5) we believe we will have a 70 percent shortfall of capacity in three to five years if something is not done to improve conditions.

Wisconsin. Capacity problems are mostly short-term and localized. Long-distance hauling sometimes is needed on an interim basis. Replacement (new or expanded) landfills are being sited in the State at the rate of about 10 to 20 per year. The State siting process is the same for both new and expanded landfills. It is a long process (two to five years), but does allow siting to take place.

Wyoming. A few areas of the State now have capacity problems, mainly Teton County, near Yellowstone, which is having a problem siting a landfill. The Federal Bureau of Land Management is no longer leasing land cheaply and in the next 10 years, siting will be a Statewide problem.

Appendix D

STATE SUBTITLE D PROGRAM REGULATIONS FOR MUNICIPAL WASTE LANDFILLS[1,2,3], SURFACE IMPOUNDMENTS[4], LAND APPLICATION UNITS[5], AND WASTE PILES[6]

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[1] PEI Associates. State Subtitle D Regulations on Municipal Solid Waste Landfills, Final Draft Report. Contract No. 68-01-7075, U.S. EPA, OSWER, Washington, D.C., 1986.

[2] U.S. EPA. Background Document: Updated Review of Selected Provisions of State Solid Waste Regulations, Criteria for Municipal Solid Waste Landfills (40 CFR Part 258) - Subtitle D of the Resource Conservation and Recovery Act (RCRA), Draft. Washington, D.C., December 1987.

[3] Westat, Inc. Census of State and Territorial Subtitle D Nonhazardous Waste Programs. Contract No. 68-01-7047, U.S. EPA, OSWER, Washington, D.C., 1986.

[4] PEI Associates. State Subtitle D Regulations on Surface Impoundments, Draft Volume II. Contract No. 68-02-3890, U.S. EPA, OSWER, Washington, D.C., 1986.

[5] PEI Associates. State Subtitle D Regulations on Land Treatment, Draft Volume III. Contract No. 68-02-3890, U.S. EPA, OSWER, Washington, D.C., 1986.

[6] PEI Associates. State Subtitle D Regulations on Waste Piles, Draft Volume IV. Contract No. 68-02-3890, U.S. EPA, OSWER, Washington, D.C., 1986.

Table D-1. SPECIFIC PERMIT REQUIREMENTS FOR MUNICIPAL LANDFILLS

State	Soil Conditions	Ground-water Information	Surface Water Information	Total Acreage	Life of Facility	Future Use	P.E. Certification
Alabama	X	X			X		X
Alaska	X	X	X				
Arizona		X	X				
Arkansas	X	X	X		X	X	X
California	X	X	X	X	X	X	X
Colorado	X	X	X	X	X		
Connecticut	X	X			X	X	X
Delaware		X	X				X
Florida	X	X	X	X	X		X
Georgia							
Hawaii							
Idaho		X	X	X			
Illinois	X	X	X	X			X
Indiana	X		X			X	
Iowa	X	X		X			
Kansas				X			X
Kentucky	X	X	X	X	X		X
Louisiana	X	X					X
Maine	X	X	X				
Maryland	X	X	X	X	X		X
Massachusetts	X	X	X		X		
Michigan	X	X	X			X	X
Minnesota	X	X	X				
Mississippi							
Missouri	X	X	X				X
Montana	X	X	X	X			
Nebraska	X	X	X				
Nevada	X	X					
New Hampshire	X	X			X		
New Jersey		X		X	X	X	X
New Mexico			X	X	X		

Table D-1. (continued)

State	Soil Conditions	Ground-water Information	Surface Water Information	Total Acreage	Life of Facility	Future Use	P.E. Certification
New York	X	X	X		X		X
North Carolina	X	X	X				
North Dakota	X	X	X				
Ohio	X	X					
Oklahoma	X	X	X		X		
Oregon	X	X	X		X	X	X
Pennsylvania	X	X	X		X	X	
Rhode Island	X	X	X		X	X	
South Carolina	X	X	X				X
South Dakota		X	X				
Tennessee			X				
Texas	X	X	X	X	X	X	X
Utah	X	X	X	X			
Vermont	X	X	X	X			X
Virginia							X
Washington							
West Virginia	X	X	X				
Wisconsin	X	X	X		X	X	X
Wyoming	X	X			X	X	
American Samoa							
Guam	X	X	X		X	X	
North Mariana Islands	X		X				X
Puerto Rico		X	X				X
Virgin Islands							
TOTAL	39	43	38	15	21	13	23

SOURCE: Reference 1.

Table D-2. DESIGN CRITERIA FOR MUNICIPAL LANDFILLS

State	Liner Design	Leachate Management	Run-on/run-off Controls	Gas Controls
Alabama	X		X	X
Alaska	X	X	X	X
Arizona			X	
Arkansas		X	X	
California	X	X	X	X
Colorado		X		X
Connecticut			X	X
Delaware	X	X	X	X
Florida	X	X	X	X
Georgia			X	X
Hawaii				
Idaho				X
Illinois		X	X	
Indiana			X	X
Iowa			X	X
Kansas			X	X
Kentucky	X	X	X	X
Louisiana	X		X	
Maine			X	
Maryland	X	X	X	
Massachusetts	X	X	X	
Michigan	X	X	X	X
Minnesota		X	X	X
Mississippi	X	X	X	X
Missouri	X	X	X	
Montana	X	X	X	X
Nebraska	X	X		X
Nevada			X	
New Hampshire				X
New Jersey		X	X	X
New Mexico			X	

Table D-2. (continued)

State	Liner Design	Leachate Management	Run-on/Run-off Controls Gas Controls	Gas Controls
New York	X	X	X	X
North Carolina			X	X
North Dakota		X	X	X
Ohio		X	X	
Oklahoma	X	X	X	
Oregon		X	X	X
Pennsylvania		X	X	
Rhode Island			X	
South Carolina			X	X
South Dakota			X	
Tennessee			X	
Texas	X		X	X
Utah				
Vermont	X		X	
Virginia				
Washington		X		
West Virginia				X
Wisconsin	X	X	X	X
Wyoming				
American Samoa				
Guam				
North Mariana Islands		X	X	X
Puerto Rico		X	X	X
Virgin Islands				X
TOTAL	19	27	42	31

SOURCE: Reference 1.

Table D-3. UPDATED REVIEW OF DESIGN, OPERATION AND CLOSURE STANDARDS FOR MUNICIPAL SOLID WASTE LANDFILLS

State	Liners			LCS			Final Cover			G W M			C A	
	NS	PS	D S	NS	PS	D S	NS	PS	D S	NS	PS	D S	NS	PS
Alabama			X		X				X		X		X	
Alaska	X			X					X	X*			X*	
Arizona	X			X					X	X*			X*	
Arkansas		X			X				X	X*			X	
California			X		X				X			X		X
Colorado	X*			X*					X		X		X*	
Connecticut	X*			X*					X		X			X
Delaware		X			X				X		X		X*	
Florida		X	X		X	X		X			X		X	
Georgia	X*			X*					X	X*			X*	
Hawaii	X			X					X		X		X	
Idaho	X*				X				X		X		X*	
Illinois	X			X*				X		X			X	
Indiana			X			X			X		X			X
Iowa		X			X				X		X		X*	
Kansas	X*			X*			X*				X		X	
Kentucky			X		X				X			X		X
Louisiana			X	X					X		X		X*	
Maine		X			X				X		X		X	
Maryland			X		X				X		X			X
Massachusetts	X*			X*					X	X*			X*	
Michigan			X			X			X			X		X
Minnesota			X			X			X			X	X	
Mississippi		X		X*					X		X		X*	
Missouri			X			X			X		X		X	
Montana	X*			X*					X		X		X*	
Nebraska	X*				X				X		X			X
Nevada	X			X					X	X*			X*	

Table D-3. (continued)

State	Liners			LCS			Final Cover			GWM			CA	
	NS	PS	DS	NS	PS	DS	NS	PS	DS	NS	PS	DS	NS	PS
New Hampshire	X*			X*					X		X		X	
New Jersey	X				X			X			X		X	
New Mexico	X			X					X	X			X	
New York			X		X				X		X		X	
N. Carolina	X*				X				X		X			X
N. Dakota	X*				X				X		X		X*	
Ohio	X*				X				X		X			X
Oklahoma			X		X				X		X		X	
Oregon	X*				X				X		X			X
Pennsylvania			X			X*			X		X		X*	
Rhode Island	X			X					X		X			X
S. Carolina		X		X					X		X		X	
S. Dakota	X			X					X	X*			X*	
Tennessee	X*			X*					X	X				X
Texas			X	X					X		X			X
Utah			X	X					X	X			X	
Vermont	X			X*					X		X		X	
Virginia	X*			X*					X	X*			X	
Washington		X			X				X	X			X*	
W. Virginia	X*			X*			X*			X*			X	
Wisconsin		X		X*					X		X		X	
Wyoming	X*			X*					X		X		X	
American Samoa	X			X			X			X			X*	
Guam	X*				X				X		X		X	
Northern Marianas	X				X		X			X			X	
Puerto Rico	X*			X			X*				X			X
Virgin Islands	X			X			X			X			X	
Totals	32	9	15	29	21	6	6	3	46	17	34	4	41	14
	19*			15*			3*			9*			18*	

SOURCE: Reference 2.

NS = No Standard.
PS = Performance Standard.
DS = Design Standard.
* = Possibly in guidance based on 1986 Subtitle D census [3].

Table D-4. OPERATION AND MAINTENANCE STANDARDS FOR MUNICIPAL SOLID WASTE LANDFILLS

State	Waste Management	Leachate Controls	Gas Controls	Cover	Safety	Other O&M Controls
Alabama	X	X	X	X	X	X
Alaska	X	X	X	X	X	X
Arizona	X			X	X	X
Arkansas	X	X		X	X	X
California	X	X	X	X	X	X
Colorado	X	X	X	X	X	X
Connecticut	X			X	X	X
Delaware	X	X		X	X	X
Florida	X	X	X	X	X	X
Georgia	X			X	X	X
Hawaii	X	X		X	X	X
Idaho	X	X		X	X	X
Illinois	X	X		X	X	X
Indiana	X			X	X	X
Iowa	X	X		X	X	X
Kansas	X		X		X	
Kentucky	X	X	X	X	X	X
Louisiana	X	X		X	X	X
Maine	X	X	X	X	X	X
Maryland	X	X		X	X	X
Massachusetts	X	X	X	X	X	X
Michigan	X	X		X	X	X
Minnesota	X	X		X	X	X
Mississippi	X	X	X	X	X	X
Missouri	X	X	X	X	X	X
Montana	X	X		X	X	X
Nebraska	X	X			X	X
Nevada	X	X		X	X	X
New Hampshire	X		X	X	X	X
New Jersey	X	X	X	X		X
New Mexico	X			X	X	X

Table D-4. (continued)

State	Waste Management	Leachate Controls	Gas Controls	Cover	Safety	Other O&M Controls
New York	X	X	X	X	X	X
North Carolina	X	X	X	X	X	X
North Dakota	X	X		X	X	X
Ohio	X	X		X	X	X
Oklahoma	X	X	X	X	X	X
Oregon	X	X	X		X	X
Pennsylvania	X	X			X	X
Rhode Island	X			X	X	X
South Carolina	X			X	X	X
South Dakota	X	X		X	X	X
Tennessee	X			X	X	X
Texas	X	X	X	X	X	X
Utah	X			X	X	X
Vermont	X			X	X	X
Virginia	X			X	X	X
Washington	X	X		X	X	X
West Virginia	X		X	X	X	X
Wisconsin	X	X	X	X	X	X
Wyoming	X		X	X	X	X
American Samoa	X					
Guam	X	X	X	X	X	X
North Mariana Islands				X	X	X
Puerto Rico					X	X
Virgin Islands						
TOTAL	52	36	22	48	52	52

SOURCE: Reference 1.

Table D-5. LOCATION STANDARDS AND RESTRICTIONS FOR MUNICIPAL SOLID WASTE LANDFILLS

State	Floodplain Protection	Minimum Distances	Critical Habitat	Geologically Sensitive Areas	Soil Conditions
Alabama	X	X	X	X	
Alaska	X	X			
Arizona					
Arkansas	X	X			X
California	X	X		X	
Colorado	X	X			
Connecticut	X	X	X		
Delaware		X			
Florida	X	X		X	
Georgia					
Hawaii	X				
Idaho					
Illinois					
Indiana	X	x			
Iowa	X	X			
Kansas	X	x	X		
Kentucky	X	X	X		
Louisiana	X	X	X		
Maine	X	X	X		
Maryland					
Massachusetts	X	X	X		
Michigan	X	X			
Minnesota	X	X			
Mississippi	X	X			
Missouri	X	X			
Montana	X	X			
Nebraska	X	X			
Nevada		X			
New Hampshire	X		X		
New Jersey		X			
New Mexico		X			

Table D-5. (continued)

State	Floodplain Protection	Minimum Distances	Critical Habitat	Geologically Sensitive Areas	Soil Conditions
New York		X	X		X
North Carolina	X	X	X		
North Dakota					
Ohio	X	X			
Oklahoma	X	X			
Oregon	X				
Pennsylvania	X				
Rhode Island	X	X	X		
South Carolina					
South Dakota	X	X	X		
Tennessee	X	X			
Texas	X	X	X		
Utah		X			
Vermont	X	X			
Virginia					
Washington		X			
West Virginia	X		X		
Wisconsin	X	X			
Wyoming		X			
American Samoa					
Guam	X	X	X		
North Mariana Islands			X	X	
Puerto Rico	X	X			
Virgin Islands					
TOTAL	36	39	16	4	2

SOURCE: Reference 1.

Table D-6. MONITORING REQUIREMENTS FOR MUNICIPAL SOLID WASTE LANDFILLS

State	Ground Water	Surface Water	Leachate	Air
Alabama	X			
Alaska	X	X	X	
Arizona	X			
Arkansas			X	
California	X		X	
Colorado	X			
Connecticut	X			
Delaware	X		X	
Florida	X		X	
Georgia				
Hawaii	X			
Idaho	X			
Illinois	X	X	X	
Indiana	X		X	
Iowa	X			
Kansas	X	X	X	
Kentucky	X			
Louisiana	X			
Maine	X	X		
Maryland	X		X	
Massachusetts	X		X	
Michigan	X	X	X	
Minnesota	X	X		
Mississippi				
Missouri	X		X	
Montana	X			
Nebraska			X	
Nevada				
New Hampshire	X			
New Jersey	X		X	
New Mexico				

Table D-6. (continued)

State	Ground Water	Surface Water	Leachate	Air
New York	X			
North Carolina	X	X	X	
North Dakota	X		X	
Ohio	X		X	
Oklahoma	X		X	
Oregon	X			
Pennsylvania	X		X	
Rhode Island	X			
South Carolina	X			
South Dakota	X	X		
Tennessee				
Texas	X		X	
Utah				
Vermont	X			
Virginia				
Washington			X	
West Virginia	X			
Wisconsin	X	X	X	
Wyoming	X			
American Samoa				
Guam	X	X	X	
North Mariana Islands	X			
Puerto Rico				
Virgin Islands				
TOTAL	42	10	23	0

SOURCE: Reference 1.

Table D-7. CLOSURE, POST-CLOSURE, AND FINANCIAL RESPONSIBILITY REQUIREMENTS FOR MUNICIPAL SOLID WASTE LANDFILLS

State	Closure Requirements	Post-Closure Requirements	Financial Responsibility Requirements
Alabama	X	X	
Alaska	X	X	
Arizona	X	X	
Arkansas	X	X	X
California	X	X	X
Colorado	X	X	
Connecticut	X	X	X
Delaware	X	X	
Florida	X	X	X
Georgia	X	X	
Hawaii	X	X	
Idaho	X	X	X
Illinois	X	X	
Indiana	X	X	
Iowa	X	X	
Kansas	X	X	X
Kentucky	X	X	X
Louisiana	X	X	X
Maine	X	X	
Maryland	X	X	
Massachusetts	X	X	X
Michigan	X	X	X
Minnesota	X	X	
Mississippi	X	X	
Missouri	X	X	
Montana	X		
Nebraska	X	X	X
Nevada	X		
New Hampshire	X	X	
New Jersey	X	X	X
New Mexico	X		

Table D-7. (continued)

State	Closure Requirements	Post-Closure Requirements	Financial Responsibility Requirements
New York	X	X	X
North Carolina	X	X	
North Dakota	X		
Ohio	X	X	
Oklahoma	X	X	X
Oregon	X	X	X
Pennsylvania	X		
Rhode Island	X	X	X
South Carolina	X	X	
South Dakota	X	X	
Tennessee	X	X	
Texas	X	X	X
Utah	X		
Vermont	X	X	X
Virginia	X		
Washington	X	X	
West Virginia			
Wisconsin	X	X	X
Wyoming	X	X	
American Samoa			
Guam	X	X	X
Northern Mariana Islands	X	X	X
Puerto Rico			
Virgin Islands			
TOTAL	51	44	21

SOURCE: Reference 1.

Table D-8. PERMIT REQUIREMENTS FOR SURFACE IMPOUNDMENTS

State	Gen. Permit Req.	Soil Cond.	Ground-water Information	Surface Water Information	Total Acreage	Life of Facility	Future Use	P.E. Certif.
California	X	X	X	X	X	X	X	X
Colorado	X	X	X	X	X	X		
Florida	X							
Georgia	X							X
Illinois	X							X
Louisiana	X	X	X					X
Montana	X	X	X	X	X			
Nebraska	X							X
New Hampshire	X	X	X	X				X
New Jersey	X				X			X
New York	X							X
Oregon	X	X	X	X		X	X	X
South Dakota	X							
Texas	X	X	X		X	X	X	X
Wisconsin	X	X	X	X	X	X	X	X
Puerto Rico	X			X				X
TOTAL	16	8	8	7	6	5	4	12

SOURCE: Reference 4.

Table D-9. DESIGN CRITERIA FOR SURFACE IMPOUNDMENTS

State	Liner Design	Leachate Management	Run-on/Run-off Control	Dike Stability and Air Protection	Security Requirements
California	X	X	X	X	X
Colorado	X	X	X	X	X
Florida		X			
Georgia					
Illinois					
Louisiana	X	X	X	X	X
Montana			X		X
Nebraska	X		X	X	X
New Hampshire			X	X	X
New Jersey					
New York	X	X		X	X
Oregon		X	X		
South Dakota					
Texas	X	X	X	X	X
Wisconsin	X	X	X	X	X
Puerto Rico					
TOTAL	7	11	9	8	9

SOURCE: Reference 4.

Table D-10. OPERATIONS AND MAINTENANCE STANDARDS FOR SURFACE IMPOUNDMENTS

State	Waste Management	Leachate Controls	Cover	Safety	Other O&M Controls
California	X	X		X	X
Colorado	X	X	X	X	X
Florida		X			
Georgia					
Illinois					
Louisiana	X	X	X	X	X
Montana		X		X	X
Nebraska		X		X	
New Hampshire	X			X	X
New Jersey		X			
New York		X		X	X
Oregon		X		X	
South Dakota		X			X
Texas	X	X		X	X
Wisconsin	X	X		X	X
Puerto Rico		X		X	X
TOTAL	6	13	2	11	10

SOURCE: Reference 4.

Table D-11. LOCATION STANDARDS AND RESTRICTIONS FOR SURFACE IMPOUNDMENTS

State	Floodplain Protection	Minimum Distances	Critical Habitat	Geologically Sensitive Areas	Soil Conditions
California	X	X		X	
Colorado	X				
Florida		X			
Georgia					
Illinois					
Louisiana	X	X	X	X	
Montana	X	X		X	X
Nebraska	X	X			
New Hampshire	X				
New Jersey					
New York	X				X
Oregon					
South Dakota	X	X			
Texas	X	X	X	X	
Wisconsin	X	X	X	X	
Puerto Rico	X	X	X		
TOTAL	11	9	4	5	2

SOURCE: Reference 4.

Table D-12. MONITORING REQUIREMENTS FOR SURFACE IMPOUNDMENTS

State	Ground Water	Surface Water	Leachate	Air
California	X		X	
Colorado	X		X	
Florida				X
Georgia	X			
Illinois				
Louisiana	X		X	X
Montana	X			
Nebraska			X	
New Hampshire	X			X
New Jersey			X	
New York	X	X		X
Oregon				
South Dakota	X	X	X	X
Texas	X			X
Wisconsin	X	X	X	X
Puerto Rico	X	X		X
TOTAL	11	4	7	8

SOURCE: Reference 4.

Table D-13. CLOSURE, POST-CLOSURE, AND FINANCIAL RESPONSIBILITY REQUIREMENTS FOR SURFACE IMPOUNDMENTS

State	Closure Requirements	Post-closure Requirements	Financial Responsibility Requirements
California	X	X	X
Colorado	X	X	
Florida			
Georgia			
Illinois	X	X	
Louisiana	X	X	X
Montana			
Nebraska	X		
New Hampshire	X	X	
New Jersey			
New York	X	X	X
Oregon	X	X	X
South Dakota	X	X	
Texas	X	X	X
Wisconsin	X	X	X
Puerto Rico			
TOTAL	11	10	6

SOURCE: Reference 4.

Table D-14. PERMIT REQUIREMENTS FOR LAND APPLICATION UNITS

State	Gen. Permit Req.	Soil Cond.	Ground-water Information	Surface Water Information	Total Acreage	Life of Facility	Future Use	P.E. Certif.
Alaska	X			X				
Arkansas	X			X		X	X	
California	X	X	X	X	X	X	X	X
Colorado	X	X	X	X	X	X		
Florida	X							
Georgia	X							X
Illinois	X							X
Iowa	X							X
Kentucky	X	X	X	X				
Louisiana	X	X	X			X		
Michigan	X		X					X
Mississippi	X							
Montana	X	X	X	X	X			
Nebraska	X		X	X				X
New Hampshire	X							
New York	X							X
Oklahoma	X			X		X		X
South Carolina	X	X				X		X
South Dakota	X							
Texas	X	X	X		X	X	X	X
Vermont	X							
Wisconsin	X	X	X	X	X	X	X	X
Puerto Rico	X			X				X
TOTAL	23	8	9	10	5	8	4	12

SOURCE: Reference 5.

Table D-15. DESIGN CRITERIA FOR LAND APPLICATION UNITS

State	Environmental Criteria	Leachate Management	Air Protection	Run-on/Run-off Control	Temp. Storage System Design	Security Requirements
Alaska				X		X
Arkansas						
California		X		X	X	X
Colorado			X	X		X
Florida		X			X	X
Georgia						
Illinois						
Iowa					X	X
Kentucky	X			X		X
Louisiana		X		X		X
Michigan					X	X
Mississippi						
Montana				X		X
Nebraska				X	X	
New Hampshire			X	X		X
New York		X		X		X
Oklahoma		X		X		
South Carolina				X		X
South Dakota						
Texas		X	X	X	X	X
Vermont						
Wisconsin		X		X	X	X
Puerto Rico						
TOTAL	1	7	3	13	7	14

SOURCE: Reference 5.

Table D-16. OPERATION AND MAINTENANCE STANDARDS FOR LAND APPLICATION UNITS

State	Waste Management	Waste Application	Crop Management	Leachate Management	Safety Controls	Other O&M Controls
Alaska		X			X	X
Arkansas	X				X	
California				X	X	X
Colorado	X				X	
Florida	X	X	X	X	X	X
Georgia	X	X				
Illinois						
Iowa	X				X	X
Kentucky	X	X	X		X	X
Louisiana	X	X	X		X	X
Michigan	X	X			X	X
Mississippi	X	X	X		X	X
Montana					X	X
Nebraska	X	X	X		X	X
New Hampshire		X			X	X
New York	X	X		X	X	X
Oklahoma				X		X
South Carolina					X	X
South Dakota						X
Texas	X	X	X	X	X	X
Vermont						
Wisconsin	X	X	X	X	X	X
Puerto Rico		X			X	X
TOTAL	13	13	7	6	18	18

SOURCE: Reference 5.

Table D-17. LOCATION STANDARDS AND RESTRICTIONS FOR LAND APPLICATION UNITS

State	Floodplain Protection	Minimum Distances	Critical Habitat	Geologically Sensitive Areas	Soil Conditions
Alaska	X	X			
Arkansas					
California	X	X		X	
Colorado	X				
Florida		X		X	
Georgia					
Illinois					
Iowa					
Kentucky	X	X	X	X	
Louisiana	X	X	X		X
Michigan	X	X			
Mississippi		X			
Montana	X	X		X	X
Nebraska		X			
New Hampshire	X				
New York	X				
Oklahoma		X			
South Carolina					
South Dakota	X	X			
Texas	X	X	X	X	
Vermont					
Wisconsin	X	X	X	X	
Puerto Rico	X	X		X	
TOTAL	13	14	4	7	2

SOURCE: Reference 5.

Table D-13. MONITORING REQUIREMENTS FOR LAND APPLICATION UNITS

State	Ground Water	Surface Water	Leachate	Soil	Air
Alaska	X	X			
Arkansas					
California	X	X	X		
Colorado	X				X
Florida	X		X	X	
Georgia	X				
Illinois					
Iowa					
Kentucky	X			X	X
Louisiana	X			X	X
Michigan					
Mississippi					
Montana	X		X		
Nebraska				X	
New Hampshire	X				X
New York	X			X	
Oklahoma	X				
South Carolina					
South Dakota	X	X		X	X
Texas	X		X	X	
Vermont					
Wisconsin	X	X	X	X	X
Puerto Rico	X	X	X		X
TOTAL	15	5	6	8	7

SOURCE: Reference 5.

Table D-19. CLOSURE, POST-CLOSURE, AND FINANCIAL REQUIREMENTS FOR LAND APPLICATION UNITS

State	Closure Requirements	Post-closure Requirements	Financial Responsibility Requirements
Alaska	X	X	
Arkansas			
California	X	X	X
Colorado	X	X	
Florida			
Georgia			
Illinois	X	X	X
Iowa			
Kentucky		X	
Louisiana	X	X	X
Michigan			
Mississippi	X	X	
Montana			
Nebraska			
New Hampshire			
New York	X	X	
Oklahoma			X
South Carolina	X		
South Dakota	X	X	
Texas	X	X	
Vermont			
Wisconsin	X	X	
Puerto Rico			
TOTAL	11	11	4

SOURCE: Reference 5.

Table D-20. SPECIFIC PERMIT REQUIREMENTS FOR WASTE PILES

State	Soil Conditions	Ground-water Information	Surface Water Information	Total Acreage	Life of Facility	Future Use	P.E. Cert.
Alabama	X	X			X		X
Arkansas	X	X	X		X	X	X
California	X	X	X	X	X	X	X
Delaware							
Florida							
Georgia							
Idaho							
Illinois							X
Iowa							X
Maine							X
Maryland							X
Minnesota	X		X				X
Mississippi							
Missouri							X
Nebraska	X	X	X				
Nevada							
New Jersey				X			X
New York							X
Ohio	X	X	X			X	
Oklahoma				X	X		X
Oregon	X	X	X		X	X	X
Pennsylvania					X	X	X
South Dakota							
Tennessee			X				
Texas					X		X
Washington							
West Virginia							
Wisconsin	X	X	X				X
Wyoming	X	X	X		X	X	
Puerto Rico			X				X
TOTAL	9	8	10	3	8	6	17

SOURCE: Reference 6.

Table D-21. DESIGN CRITERIA FOR WASTE PILES

State	Liner Design	Leachate Collection	Gas Controls	Run-on/ Run-off Controls	Security Requirements
Alabama	X		X	X	X
Arkansas					
California	X			X	X
Delaware					
Florida				X	
Georgia					X
Idaho					
Illinois					
Iowa					X
Maine					X
Maryland			X		X
Minnesota					
Mississippi				X	
Missouri			X		X
Nebraska	X		X	X	X
Nevada					
New Jersey					
New York					X
Ohio	X		X	X	X
Oklahoma	X			X	X
Oregon				X	X
Pennsylvania				X	X
South Dakota					
Tennessee					X
Texas	X		X	X	X
Washington				X	X
West Virginia					X
Wisconsin				X	X
Wyoming	X				X
Puerto Rico				X	
TOTAL	7	0	6	13	19

SOURCE: Reference 6.

Table D-22. OPERATION AND MAINTENANCE STANDARDS FOR WASTE PILES

State	Waste Management	Leachate Controls	Gas Controls	Cover	Safety	Other O&M Requirements
Alabama		X	X		X	X
Arkansas						
California	X	X		X	X	X
Delaware						
Florida		X			X	X
Georgia					X	X
Idaho					X	X
Illinois						
Iowa	X				X	X
Maine	X				X	X
Maryland	X				X	X
Minnesota					X	X
Mississippi					X	
Missouri	X				X	X
Nebraska		X	X	X	X	X
Nevada					X	
New Jersey	X				X	X
New York		X			X	X
Ohio	X				X	X
Oklahoma		X			X	X
Oregon		X			X	X
Pennsylvania		X			X	X
South Dakota						X
Tennessee					X	X
Texas	X		X		X	X
Washington					X	X
West Virginia	X				X	X
Wisconsin		X	X	X	X	X
Wyoming	X				X	X
Puerto Rico					X	X
TOTAL	10	9	4	3	26	25

SOURCE: Reference 6.

Table D-23. LOCATION STANDARDS AND RESTRICTIONS FOR WASTE PILES

State	Floodplain Protection	Minimum Distances	Critical Habitat	Geologically Sensitive Areas	Soil Conditions
Alabama	X	X			
Arkansas					
California	X	X			X
Delaware					
Florida		X			
Georgia					
Idaho					
Illinois					
Iowa					
Maine	X	X			
Maryland					
Minnesota			X		
Mississippi					
Missouri					
Nebraska	X	X	X		
Nevada		X			
New Jersey					
New York	X				
Ohio					
Oklahoma	X	X			
Oregon			X	X	
Pennsylvania	X	X			
South Dakota	X			X	
Tennessee					
Texas	X	X			
Washington					
West Virginia	x				
Wisconsin					
Wyoming					
Puerto Rico	X				X
TOTAL	11	9	3	2	2

SOURCE: Reference 6.

Table D-24. MONITORING REQUIREMENTS FOR WASTE PILES

State	Ground Water	Surface Water	Leachate	Air
Alabama	X		X	X
Arkansas	X			
California	X		X	
Delaware				
Florida	X		X	
Georgia				
Idaho				
Illinois				
Iowa				
Maine				
Maryland				
Minnesota				
Mississippi				
Missouri	X			
Nebraska	X		X	
Nevada				
New Jersey				
New York	X		X	
Ohio	X		X	
Oklahoma	X	X	X	
Oregon			X	
Pennsylvania			X	
South Dakota	X	X		X
Tennessee				
Texas	X			
Washington				
West Virginia	X	X		
Wisconsin	X	X	X	
Wyoming				
Puerto Rico	X	X		
TOTAL	14	5	10	2

SOURCE: Reference 6.

Table D-25. CLOSURE, POST-CLOSURE, AND FINANCIAL RESPONSIBILITY REQUIREMENTS FOR WASTE PILES

State	Closure	Post-closure	Financial Responsibility Requirements
Alabama	X	X	
Arkansas			
California	X	X	X
Delaware			
Florida			
Georgia	X		
Idaho			
Illinois	X	X	
Iowa			
Maine	X		
Maryland			
Minnesota	X		
Mississippi			
Missouri			
Nebraska	X		
Nevada			
New Jersey			
New York	X	X	X
Ohio	X	X	
Oklahoma	X		X
Oregon	X	X	X
Pennsylvania			
South Dakota	X	X	
Tennessee			
Texas	X	X	X
Washington			
West Virginia			
Wisconsin	X	X	X
Wyoming			
Puerto Rico			
TOTAL	14	9	6

SOURCE: Reference 6.

Appendix E

THE SUBTITLE D GROUND-WATER RISK MODEL

APPENDIX E

The following are summaries of each submodel used for the Subtitle D risk analysis. The submodels simulate:

- A) pollutant release,
- B) fate and transport,
- C) exposure, and
- D) impacts and corrective action.

A. Pollutant Release

Liner Failure Submodel

The failure/release submodel uses Monte Carlo simulation to estimate the probability and time of failure (defined as release to the unsaturated zone) as well as the quantity of leachate released. The submodel used a "fault tree" structure that traces each possible failure event from all possible combinations of basic events (e.g., liner failure, infiltration of liquid) that could combine to cause failure. The basic events are assumed to occur at random, following specified probability distributions. The output is a distribution of the year of failure and pollutant release rate for a given facility design and environmental setting.

Leachate Quality Submodel

The leachate quality submodel simulates the concentrations of chemical constituents in leachate released from the landfill between years 1 and 100. Given differences in the leaching behavior of constituents, the submodel utilizes three different modeling approaches to simulate the concentrations of inorganics, biodegradable organics, and synthetic organics in leachate. The submodel applies the appropriate algorithm to calculate the concentration of each leachate constituent for each year. The concentration is then combined with the release volume calculated by the failure/release submodel to calculate the mass flux of the constituent across the landfill/subgrade boundary.

One representative leachate, consisting of eight constituents of concern (COC), was simulated. This leachate is intended to represent typical leachates generated from existing municipal solid waste landfills (MSWLFs), some of which received at least limited quantities of hazardous waste. Leachate composition data covering 212 chemical constituents were obtained for 44 operating MSWLFs. The eight COC were selected based on potential for causing human health risk or resource damage, given their observed concentrations in the leachate data, toxicity to humans, regulatory limits under the Safe Drinking Water Act, taste and odor thresholds, and mobility and persistence in the subsurface environment.

The eight COC and the effect of concern for each are given below:

Vinyl chloride	Human health risk (cancer)
Arsenic	Human health risk (cancer)
Iron	Resource damage (taste and odor)
1, 1, 2, 2, - Tetrachloroethane	Human health risk (cancer)
Dichloromethane	Human health risk (cancer)
Antimony	Human health risk (systemic poison)
Carbon tetrachloride	Human health risk (cancer)
Phenol	Resource damage (taste and odor)

For this analysis, the median concentrations from the data base were used. The Agency considered using the 90th percentile concentration levels for the analysis. However, it was estimated that the risk associated with the 90th percentile levels in the leachate data would be approximately one order of magnitude higher than that simulated for the median concentrations. The 90th percentile represents the higher end of the leachate data. Available data on leachate from MSWLFs are limited, especially for characterization of organics. The constituents and concentrations that best characterize the leachate are subject to change in the future as the data base is expanded.

B. Fate and Transport

Unsaturated and Saturated Zone Transport Submodels

Subsurface transport modeling addresses transport through both the unsaturated zone and the saturated zone. The Subtitle D Risk Model uses the McWhorter-Nelson wetting front model to calculate the delay between the time of failure and the time that contaminants reach an underlying aquifer. The mass that breaks through the unsaturated zone then disperses through the ground water. Using an adaptation of the Random-Walk Solute Transport Model developed by Prickett, Naymik, and Londquist, the saturated zone model simulates downgradient ground-water concentrations over a period that covers 100 years of release and 200 years of saturated zone transport for each year of release. Concentrations are estimated at seven downgradient distances ranging for 10 meters to 1,500 meters. These distances define the location of wells where contamination might occur. The velocity of ground water and retardation caused by absorption of contaminants to earth materials govern the rate of constituent transport through the unsaturated and saturated zones. Retardation depends on contaminant as well as soil characteristics. Degradation is considered for those constituents that have adequate data to develop rates.

The rate at which pollutants are released to an aquifer is influenced significantly by climate and hydrogeology. Two of the most important parameters are net infiltration (precipitation minus evapotranspiration) and ground-water table depth. Net infiltration determines the amount of water that can enter a landfill as a result of precipitation. Ground-water table depth is important for two reasons. First, depth to ground water determines the thickness of the unsaturated zone, an area in which significant pollutant retardation and degradation can occur. Second, for facilities that are seasonally inundated with ground water, the inundation depth determines the rate at which ground water can flow through the waste.

These two parameters were used to define eight environmental settings for the failure/release submodel runs. The settings consist of four net infiltration categories (0.25-inch, 1-inch, 10-inch, and 20-inch) and two ground-water table depths (deep and shallow) for each infiltration regime. EPA performed a statistical analysis of U.S. Geological Survey data for each infiltration category to determine the distribution of ground-water table depths and average annual ground-water fluctuation. EPA chose the 50th and 90th water table depths to represent the shallow and deep conditions, respectively.

To model the transport of constituents in the saturated zone, EPA developed 11 generic ground-water flow fields to represent the range of hydrogeologic conditions in the United States. The flow fields were developed on the basis of data collected from ground-water supply reports for each of the USGS ground-water regions. The flow fields vary in terms of aquifer configuration, materials, and flow velocity. Five of the flow fields are single-layer aquifer systems, two contain two adjacent aquifers, three consist of an aquifer overlaid with a non-aquifer, and one contains two aquifers separated by a non-aquifer.

To estimate the frequency with which landfills are located in each of these environmental settings, EPA determined the latitudes and longitudes of over 700 landfills from the municipal landfill survey and a separate mapping effort. EPA used precipitation and other climatic data collected at weather stations near each landfill to assign the site to a net infiltration region. EPA also determined the likely DRASTIC[1] setting for each landfill, and used ground-water data characterizing these settings to assign sites to ground-water table depths and flow fields. Flow fields I and J were virtually absent from the set of characterized facilities and, therefore, were not modeled.

C. Exposure

Ground-water concentrations of chemical constituents released from landfills can cause human exposure via drinking water. EPA estimated human health risk for the maximum exposed individual (i.e., the mean of the average lifetime risks over the 300-year modeling period) and the total population using ground water as a drinking water source, residing within one mile of the facility.

EPA chose seven well distances for modeling risk: 10 meters, 60 meters, 200 meters, 400 meters, 600 meters, 1,000 meters, and 1,500 meters. EPA used preliminary results from the MSWLF survey to develop a distribution of distance from the landfill to the closest drinking water well at each site; this well distance distribution was used to develop frequency weights for each of the seven well distances. This distribution (distance to nearest well) was used to estimate risk to the maximum exposed individual. An important finding from the facility survey is that 54 percent of MSWLFs reported having no downgradient wells within one mile. Thus, because this analysis only considers risk within one mile of the facility, it is assumed there is no risk at 54 percent of the MSWLFs.

For population risk (number of predicted cases), EPA used preliminary facility survey results on distance to public and /or private wells (and the corresponding number of people served at each well) within one mile downgradient of the facility. EPA estimated that landfills with wells have a downgradient density of about 1.6 well-using people per acre. EPA calculated the affected land area associated with each exposure well and multiplied the area by the above population density to estimate the size of the exposed population for each well at sites with wells.

All exposed individuals are assumed to weigh 70 kilograms and drink two liters of water per day. The lifetime dose is calculated as the running 70-year average over an individual's lifetime.

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[1] DRASTIC: A Standardized System for Evaluating Ground-Water Pollution Potential Using Hydrogeologic Settings. U.S. EPA, 1985, EPA/600/2-85/018.

D. Impacts and Corrective Action

Health Effects Submodel (Dose-response)

Of the constituents of concern selected for modeling human health risk, five are carcinogens and one is a noncarcinogen. The approach for estimating risks for carcinogenic effects is consistent with the Agency's cancer risk assessment guidelines. Carcinogenic potencies are obtained using either the Agency's Carcinogenic Assessment Group values, which were derived from dose-response data using the 95% upper bound slopes based on a linear multistage function (when available), or a one-hit model. Both methods assume linearity at low doses and no threshold.

For noncarcinogenic effects, EPA used the Weibull equation with a threshold to predict a probability of effect. Below the threshold, risk equals zero. At doses above the threshold, risk depends on the dose, the constituent-specific threshold, and the shape of the dose-response curve.

Resource Damage Submodel

The measure of resource damage used in the model is based on the cost to replace contaminated ground water that is currently used or that may be used for drinking water. Resource damage is determined by plume area, the density of drinking water wells, the source of replacement water and its distance from the affected wells, the time the plume first appears, and whether or not ground water is currently used.

Similar to the risk analysis, preliminary results from the (Municipal) Solid Waste Landfill survey were used to derive the average well density (i.e., 1 well per 80 acres) and population served per well (128 people). These two values, along with the plume area generated by the model, were used to estimate the required size of the replacement water supply system. The Agency assumed that the replacement source is nearby ground water located at one mile distance.

Resource damage was estimated under two scenarios: use value and option value. Use value assumes that the population is currently using the ground water for drinking water, whereas option value assumes that the population is not currently using the resource for drinking water but may wish to do so in the future. For option value, the resource damage measure recognizes the probabilistic nature of future use; replacement costs are multiplied by an estimated probability of use in each time period. The present value for both option and use value are then determined at a 3 percent real discount rate. Thus, unlike the human health risk estimates, the resource damage results reflect the potential growth in the future use of ground water as a drinking water source.